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THE BELT DYNAMOMETER OF DOCTOR C. W. SIEMENS.

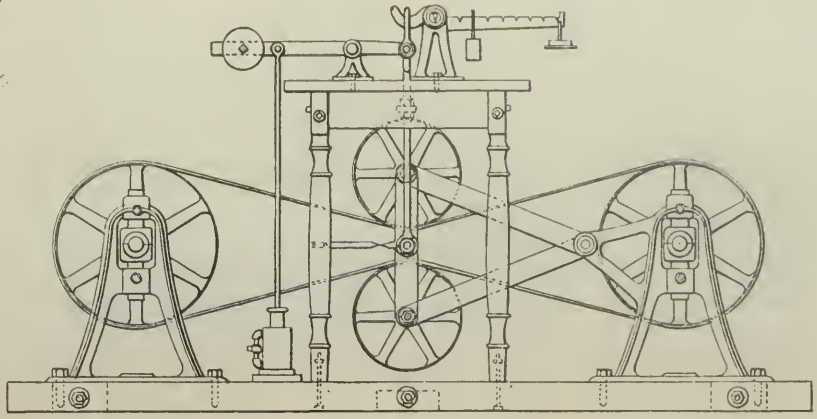
By ROBT. BRIGGS, C.E.

The accompanying illustration of a belt dynamometer after the general design employed in experiments with the Siemens dynamo-electric machine, has been prepared by the writer of this article, to meet the demand for a more quiet and equally reliable instrument of this kind than is found in the well-known geared or tooth-wheel dynamometer in common use in this country.

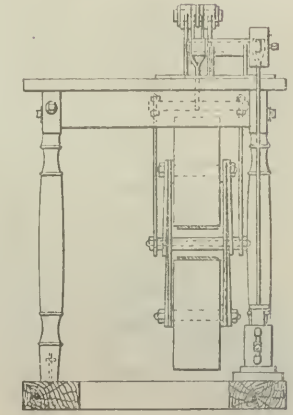
The principle involved in the construction of this dynamometer, that is, the weighing of the resulting stress from a deflected cord or band, and thus ascertaining the direct stress upon the band itself, is not new. This was one of the earliest methods of measuring the load upon a telegraphic cable when paying out, and it is believed that the method has been applied for a dynamometer in Germany for some time, but the attention of the writer was first brought to it by perusal of the paper of Messrs. Higgs and Brittle on Electrical Apparatus, in the *Proceedings of the Institution of Civil Engineers for* 1878. The illustration in that paper was sufficiently good for any mechanic to work out a practical machine, using the general details of shafting and pulleys of American practice, and the only *improvement* or novelty now presented consists in thus adapting the machine of Dr. Siemens to American convenience.

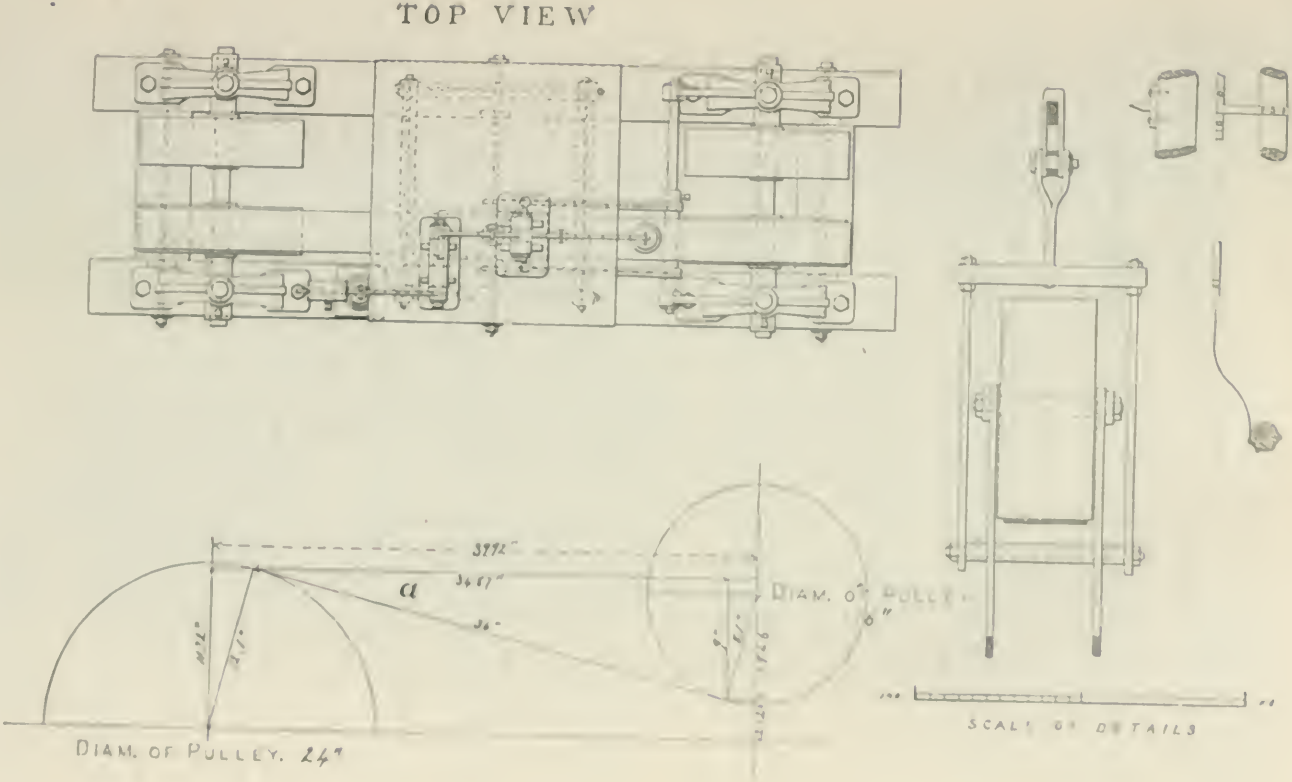
BELT DYNAMOMETER

SIDE ELEVATION



END VIEW
HANGERS REMOVED




TOP VIEW
a
DIAM. OF PULLEY
SCALE OF DETAILS

The diagram, which forms part of the illustration, will serve to explain the theory of the dynamometer.

It is established in the transmission of force by a belt, that the force exerted is the difference of strain on the two sides of the belt, multiplied by the velocity of movement of the belt itself. A belt, in its initial state, when at rest, is a continuous band, subject to a uniform strain in all its periphery, bringing into action the elasticity of the band and of the shafting or pulleys to sustain this strain. And the same equality of strain exists when the belt is running without the performance of work. [It being supposed that such running is devoid of resistance from friction or other cause.] But as one of the pulleys presents a resistance to being turned, and the other, impelled by some motor through its shaft, takes up and overcomes this resistance through the belt, the adhesion of the belt to the pulleys is now brought into action, and one side of the belt is abnormally tightened, while the other side becomes correspondently loose, and the difference of strain between the two sides becomes the measure of the force transmitted at some given velocity.

In the arrangement of pulleys and belt shown by the side elevation (see plate), it is obvious (the weight of the carrier pulleys, the frame supporting the same, and of the belt, being balanced) that when at rest or running with no resistance the system will come into equilibrium with equal but opposite angles for both the upper and lower belt. The indicator, attached to the carrier frame, will then be in the straight line between the centre of the main pulleys, and will coincide with the pointer attached to the permanent framework, which is placed also in the same line. If the belt in this position be subject to some normal strain, it is evident that a definite proportion of this strain will be exerted equally upon the axes of the carrying pulleys. If now the system be put at work, the belt will come at once to have a tight side and a loose side, and the difference of strain can be measured by the load necessary to preserve the carriers in the same position as regards the line between the centres of the main pulleys.

The resultant of strain from the deflected band varies as the sine of the angle, and to make this instrument as simple as possible the angle of the belt has been taken as such that its sine $= \frac{1}{4}$.

$$[\text{Sin.}^{-1} \tfrac{1}{4} = 14^\circ\ 29'.]$$

Let sin. $\alpha = \frac{1}{4}$; T_1 = tension of belt on tight side.

W = weight; T_2 = " " loose side.

P = force transmitte l.

$$\therefore \qquad P = T_1 - T_2 = \frac{W}{2 \sin. \alpha} = 2\ W$$

If, therefore, a certain force, W, is needed to preserve the central position of the indicator, there will have been transmitted by the belt a force $= 2\ W$.

Accepting these relations of angles and force, the relative positions of an arrangement which shall employ pulleys 24 inches in diameter for the main pulleys, and others 8 inches in diameter for the carrier pulleys, is given by the diagram, when the length of inclined belt is taken at 36 inches. An allowance of $\frac{1}{16}$ inch has been made for half the thickness of the belt when the radii of the line of the belt on the two pulleys become $12\frac{1}{16}$ and $8\frac{1}{16}$, respectively. It will be easy for any one to compute the triangle and verify the dimensions on the diagram.

The machine itself consists of a bed framing of wood, joint-bolted together, upon which is mounted a high table, also joint-bolted throughout. The bed frame carries two pairs of inverted hangers, $2\frac{1}{4}$-inch shaft, 20-inch drop, with self-oiling boxes. Each pair of hangers carry shafts $2\frac{7}{16}$ inches of diameter, with two pulleys, 24 × 7 inches, high. One of the pairs of hangers have brackets cast upon them, which form the fulcrum for the carrier frame. The carrier frame has two pulleys, 16 × 7 inches, high, and the pulley end of the frame is suspended by knife-edge pins and links to a scale beam, the P of which has half the usual weight.

With this P the scale indicates the strain transmitted by the belt without computation. The suspension frame, also, is hung by well-fitted pins and links to a counterbalance system of levers and weights, with a dash pot attachment to control the action of the dynamometer against sudden variations of work.

This dynamometer, with the proportions given, and on the supposition that 6-inch belts be used, will transfer, where the belt is strained normally upon both sides to 40·4 pounds per inch of width, 7·2 horse-power. As, however, the contact with the driving or driven pulleys can scarcely be so great as that on the main pulleys, where 210° exists, it is probable that this particular instrument cannot be held to measure the transmission of much more than 6½ horse-power. When the unbalanced strain of the two sides of the belt must amount to 47·4 pounds per inch of width, while the actual maximum strain on the tight side of the belt cannot be less 56 to 60 pounds, and may much exceed that value if the normal strain rises above 40 or 42 pounds.

HIGH RAILWAY SPEEDS.

By W. Barnet Le Van.

Read before the Franklin Institute, at its meetings, May 19th and June 15th, 1880.

Railways being now the common highways of our country, their managers naturally seek all means of accommodating and meeting the wants of the traveling community.

The active rivalry now existing between the Pennsylvania Railroad and the Bound Brook Route of the Philadelphia and Reading Railroad has resulted in giving us the most improved facilities for communication between the two principal cities of this country, and has placed our railway speed on a par with the fast time of the British express trains.

It is but a few years ago that a trip to New York and back in the same day was considered a wonderful achievement; the time occupied, being three hours each way, was thought very short, whereas to-day one can have his breakfast and go to New York, transact business and return and dine in his own house. But even the great reduction of time has not been considered sufficient to comply with the requests of rapid transit, and the two roads referred to are contemplating and preparing to run the 90 miles between Philadelphia and New York in 90 minutes.

Sixty miles an hour, as it strikes the ear, does not seem an impossibility, but if we look at it in all its bearings, and consider that it means *one mile in one minute*, or 60 *miles in* 60 *consecutive minutes*, it begins to assume proportions that seem insurmountable.

Some of the earliest locomotives ever built have run over a mile a minute, and in one instance a speed of 93 miles per hour was maintained for a few miles.

To illustrate more clearly the difficulties in running sixty miles in sixty minutes, the locomotive must be capable at all times of developing *seventy miles per hour*, so as to meet any contingency that may arise. A locomotive at seventy miles an hour passes over one hundred and two feet per second $\left(\frac{70\times 22}{15} = 102{\cdot}6\right)$. Two objects near a person, say three feet apart, pass his eye in the thirty-fifth part of a second.

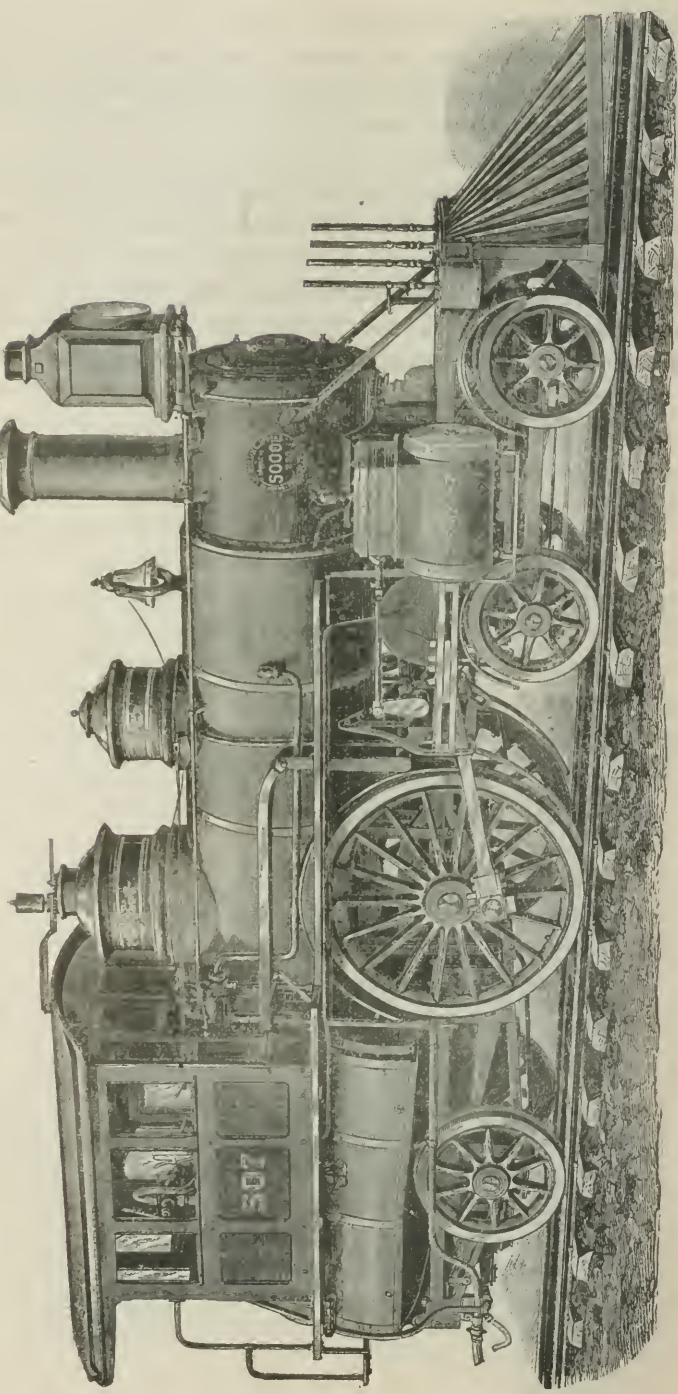
When two trains having this speed pass each other, the relative velocity will be two hundred and five feet per second; and if one of the trains were one hundred and two feet long, it would flash by in a single second. To accomplish this, supposing the driving wheels to be six and one-half feet in diameter, and the piston to change its direction in the cylinder ten times in a second, there being two cylinders to every locomotive, and the eccentrics being so adjusted that the exhaust steam discharges alternately, there are twenty discharges of steam per second, at equal intervals, and these twenty exhausts divide a second into twenty equal parts, each puff having a twentieth of a second between it and that which precedes and follows it. The ear, like the eye, is limited in the rapidity of its sensations; and, sensitive as these organs are, they are not capable of distinguishing sounds which succeed each other at intervals as short as the twentieth part of a second.

Therefore, to run sixty miles in sixty minutes continuously, and with a reasonable degree of safety, some modification in the form of engine as now built must be made. The road bed must also be in the best condition attainable, and as straight as possible, and if curves are indispensable they should not be less than 2000 feet radius.

Locomotives are distinguished as *single* or *coupled*, independently of their kind or class. When only a single pair of driving wheels is employed, the engine is said to be a single engine. When two or more pairs of driving wheels are used, connected by coupling rods, the engine is said to be coupled.

When six coupled wheels and a swing "pony truck" in front, connected by equalizing beams with the leading pair of coupled wheels, it is called *Mogul*, and when eight coupled wheels and "pony truck" it is called *Consolidation*.

To accomplish sixty miles in sixty minutes, the Baldwin Locomotive Works, of this city, have just placed on the Bound Brook route between this city and New York a new single engine, similar to those used on the fast lines in England, having but one pair of driving wheels, 6½ feet in diameter. The ordinary driving wheels of passenger engines in this country do not exceed 5½ feet, and two pair coupled together, are used. For fast speeds, with coupled driving wheels, as in ordinary use, the momentum of the parallel rods which connect the driving wheels becomes enormous, and is a source of great danger. Within a month past the parallel rod of an engine on the Pennsyl-



Locomotive No. 5000, built by the Baldwin Locomotive Works.

vania Railroad broke. It demolished the cab of the engine, and seriously injured the engineer, and detained the train over one hour.

This new engine requires no parallel rods, and the increased diameter of the wheels also reduce the number of revolutions to the mile, as well as the centrifugal force.

In the ordinary locomotive with small and coupled driving wheels, the greatest speed of the piston reaches sometimes about 1200 feet per minute with a 2 foot stroke and 5½ feet diameter driving wheels, giving about fifty-nine miles per hour; but with driving wheels 6½ feet diameter, and the same piston speed, the running rate would be about *sixty-nine miles* per hour. No more adhesion is required at high than at low speeds, assuming the load to be the same. The truth is that the amount of adhesion required to turn to account the whole power which a locomotive is capable of developing varies, inversely, according to the speed at which the engine is run, the higher the speed the less being the adhesion required. The increased resistance, according to experiments made, is in a less ratio than that of the simple velocity, so that the boiler need not exceed the limit of space afforded. The ordinary locomotive boilers do not exceed 1100 feet of heating surface and 20 square feet of fire grate. In this new locomotive the boiler has about 1400 square feet of heating surface and about 56 square feet grate surface.

The dimensions of the engine are as follows:

Diameter of cylinders, in inches,	18
Length of stroke, in inches,	24
Diameter of driving wheel, in inches,	78
Wheel-base, in feet,	21 ft. 1 in.
Distance from centre of driving wheel to centre of trailing wheel, in feet,	8

Boiler.

Boiler made of steel $\frac{7}{16}$ inch in thickness.
Diameter of boiler, 52 inches.
Number of tubes, 198 and 2 inches diameter.
Length of tubes, 12 feet 2⅞ inches.
Fire-box, 96½ long by 84 inches.

TENDER.

Capacity about 3800 gallons.
Wheels, 36 inches diameter.
Weight, filled with water and coal, 70,000 pounds.

The Bound Brook road is not fitted with water troughs between the tracks, so that the locomotive tender can pick up its water while in motion; thus, larger tenders are needed to convey sufficient water for the through trip.

By dispensing with the coupling rods and reducing the centrifugal force of the driving wheels it is evident that the design of the engine is in the right direction for safety and fast running.

The tractive force for each pound of effective pressure per square inch on the pistonswhich this engine is capable of exerting will be

$$\frac{18^2 \times 24}{78} = 99{\cdot}68 \text{ pounds.}$$

In running sixty miles per hour, on an ordinary road, which corresponds to about 258 revolutions, or a piston speed of 1034 feet per minute, and a mean effective pressure of abont 35 pounds per square inch, the tractive power exerted will be

$$\frac{18^2 \times 24 \times 35}{78} = 3489 \text{ pounds}$$

for each piston, and the horse-power for the two cylinders will be

$$HP = \frac{18^2 \times 1034 \times 35}{33000} \times 2 = 552{\cdot}72$$

To run a train sixty miles in sixty minutes between Philadelphia and New York would not be considered as remarkable, provided the track was always clear; but several large towns, cities, and bridges, some of which have draws, are, however, scattered along the route, necessitating a material reduction of speed in passing them, and thus time is lost, which must be made up by a proportionate increase in speed on those parts of the roadway which are clear and unobstructed. This increased speed must be as great, at times, as *seventy miles* an hour, as before stated.

On Friday, May 14th, 1880, I received an invitation from Messrs. Burnham, Parry, Williams & Co., to make a trip on a train to be drawn by their "new departure locomotive, No. 5000," the 5000th of their build (Philadelphia and Reading Railroad Company's No.

507), from Ninth and Green streets to Jersey City, over the Bound Brook route, without stopping, and return in the same way.

As before stated, this locomotive has only one pair of driving wheels, 78 inches in diameter.

The weight is so disposed upon the wheels that by an alteration of fulcrum, points operated by a separate steam cylinder additional weight can be thrown on the drivers at the time of starting. This shifting of the weight will give from 8000 to 9000 pounds additional on the driving wheels.

The weight of the engine, ready for attaching to the train, is 85,000 pounds, and the tender 70,000. The train going to New York consisted of four day (set up) cars, of the usual pattern, each weighing about 42,000 pounds. Weight of the train complete, about 148 tons.

The Start.

When the engine left the round house, to take its place at the head of the train, I was reminded of what Elihu Burritt says, when writing about the locomotive:

"I love to see one of those huge creatures, with sinews of brass and muscles of iron, strut forth from his stable and salute the train of cars with a dozen sonorous puffs from his iron nostrils, then fall back gently into his harness.

"There he stands champering and foaming upon the iron track, his great heart a furnace of glowing coals, his lymphatic blood boiling within his veins; the strength of a thousand horses is nerving his sinews, he pants to be gone. He would drag St. Peter's across the Desert of Sahara, if he could be hitched on."

The signal to go ahead was given at precisely 11.16 A.M., and, on account of Ninth street being more or less obstructed by teams crossing, 9½ minutes was consumed in reaching Wayne Station, distance 4·3 miles, rate of speed, per hour, 27·15 miles.

Wayne Station to Jenkintown, distance 5·8 miles, time 6·75 minutes, rate of speed 51 miles per hour.

Jenkintown to Yardley, distance 20 miles, time 19 minutes, rate of speed 63 miles per hour.

Yardley to Trenton Junction, distance 2 miles, time 2¼ minutes, rate of speed 53·3 miles per hour.

Trenton Junction to Bound Brook, distance 27·1 miles, time 25¾ minutes, rate of speed 63 miles per hour.

Bound Brook to Elizabeth, distance 20·7 miles, time 20¾ minutes, rate of speed 60 miles per hour.

Elizabeth to Jersey City, distance 11½ miles, time 14 minutes, rate of speed 49·3 miles per hour.

Total time from Ninth and Green streets, Philadelphia, to Jersey City, 89·4 miles, 98 minutes, rate of speed 54·73 miles per hour.

The Return.

On the return trip one car was added, making the total load 168 tons.

Left Jersey City at 2.07 Philadelphia time, reached Elizabeth at 2.21½, distance 11½ miles, time 14½ minutes, rate of speed 47½ miles per hour.

Elizabeth to Bound Brook, distance 20·7 miles, time 19 minutes, rate of speed 65·3 miles per hour.

Bound Brook to Trenton Junction, distance 27·1 miles, time 26·8 minutes, rate of speed 60·6 miles per hour.

Trenton Junction to Yardley, distance 2 miles, time 2⅓ minutes, rate of speed 53 miles per hour.

Yardley to Jenkintown, distance 20 miles, time 20·8 minutes, rate of speed 57·6 miles per hour.

Jenkintown to Wayne Junction, distance 5·8 miles, time 8 minutes, rate of speed 43·5 miles per hour.

Wayne Junction to Ninth and Green streets, distance 4·3 miles, time 8½ minutes, rate of speed 30·3 miles per hour.

Total time from Jersey City to Ninth and Green streets, Philadelphia, 100 minutes, distance 89·4 miles, rate of speed 53·4 miles per hour.

The best performance during the trip was in running the 2·8 miles from Willitt to Langhorne, part of which distance is an ascending grade of 16 feet per mile, in two minutes, being at the rate of *eighty-one miles per hour.*

A careful examination of all the bearings at the end of each trip showed them to be perfectly cool, which is something extraordinary for a new engine, running 90 miles without stopping.

To show the speed this engine is capable of performing, on a former trial she ran 13·8 miles in 10½ minutes, or at the rate of *seventy-eight and eighty-five hundredths* of a mile per hour.

Some idea of the steaming capacity of the boiler may be had from

the fact that a No. 9 Sellers injector, which will throw 2000 gallons of water per hour, will not keep her supplied.

The water consumed in the 98 minutes' run to Jersey City was about 3300 gallons, and on the return trip about 3600 gallons, or about 34½ gallons, or 288 pounds per minute.

Comparing this time with the fast time made by the 7.35 A. M. going east and the 3.30 P. M. coming west, on the Pennsylvania Railroad, from Germantown Junction to Jersey City and return, we have as follows:

Pennsylvania Railroad.—Germantown Junction to Jersey City, distance 84·2 miles, time 106 minutes, rate of speed 47·7 miles per hour.

Reading Railroad.—Wayne Junction to Jersey City, distance 85·1 miles, time 88½ minutes, rate of speed 57·6 miles per hour.

Jersey City to Germantown Junction, distance 84·2 miles, time 103 minutes, rate of speed 49 miles per hour.

Jersey City to Wayne Junction, distance 85·1 miles, time 91½ minutes, rate of speed 55·7 miles per hour.

Being seventeen per cent. less time going east and twelve per cent. coming west than that now made by the Pennsylvania Railroad.

The advantage of large diameter for driving wheels is in the reduction of the number of revolutions per mile. In the Baldwin engine the revolutions per mile are $\frac{1680}{6{\cdot}5} = 258$, and those of the Pennsylvania Railroad, with a 5½ foot wheel, $\frac{1680}{5{\cdot}5} = 305$, an increase of $\frac{305 - 258 \times 100}{305} = 15{\cdot}4$ per cent., and their engines being coupled, this additional number of revolutions adds to the risk by increasing the momentum of the parallel rods and tending to separate them.

It must not be supposed that 80 miles an hour is the limit of speed which a railway train may attain. Speed is a question of power and resistance, and velocities greater than 80 miles an hour, which is about 7000 feet per minute, are in use in various kinds of machinery, to wit: fan-blowers, circular saws, etc.

The writer believes that before the expiration of five years, with the present active rivalry, passengers will be set down in New York in one hour's time from this city.

The following table shows the speed in miles per hour of the *fast lines* in Europe and America.

DESTINATION.		Name of Railway.	Distance between stations in miles.	Time between stations, hours and minutes.	Av. miles per hour inc. stops.
Paris to	Marseilles,	.....	539	15·21	35
	Lyons,	.....	320	8·	40
Berlin to	Cologne,	.....	364	9·26	38½
	Magdeburg,	.....	88¾	2·7	42
Spandau to	Stendal,	Berlin & Hamb'g	57½	1·22	42
London to	Edinburgh,	Great Northern	397	9·30	42
	Plymouth,	London & S. W.	246½	6·15	41
	Holyhead,	North-Western	268	6·35	43
	Swindon,	Great Western	77¼	1·27	53½
	Rugby,	North-Western	82¼	1·42	48½
	Leicester,	Midland	99	2·13	44½
	Peterborough,	Great Northern	76¼	1·32	50
New York to	Philadelphia,	Penna. R.R.	90	2·05	43
	Washington,	"	230	6·	38
	Boston,	"	233	7·11	32
	Cincinnati,	"	757	26·30	28
	Pittsburg,	"	444	13·30	32
	Chicago,	"	912	34·20	26½
	Albany,	Hudson River	143	4·05	35
	Philadelphia,	Bound Brook	90·4	2·10	41½
Jersey City to	Wayne June.	"	85·1	1·47	47
	Gemant'n "	Penna. R.R.	84·2	1·43	49
Philadelphia to	Chicago,	"	822	23·50	35

The mean average of all the English railways is 46·2 miles per hour; French, 37·5 miles per hour; German, 40 miles per hour, and America, 37 miles per hour. The English being 20 per cent. faster than in this country.

With them, 6½ feet driving wheels are quite as common as 5½ feet wheels are with us; in fact some of the fast lines have 8 and 9 feet, and one line had 10 feet diameter.

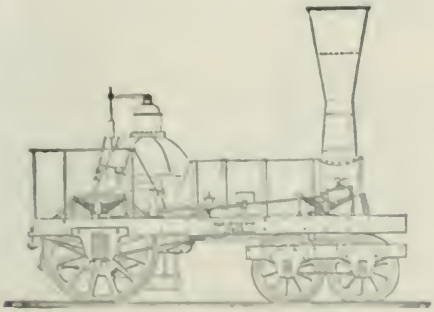
Engines with one pair of drivers are not new in this country. The *Ironsides*, built by M. W. Baldwin in 1832, had but one pair of drivers, 4½ feet in diameter. Mr. William Pettit ran her on the Phil-

adelphia and Germantown Railroad at the rate of 62 miles per hour. Dr. Patterson, of the University of Virginia, and Mr. Franklin Peale were on the engine, and timed its working on that occasion.

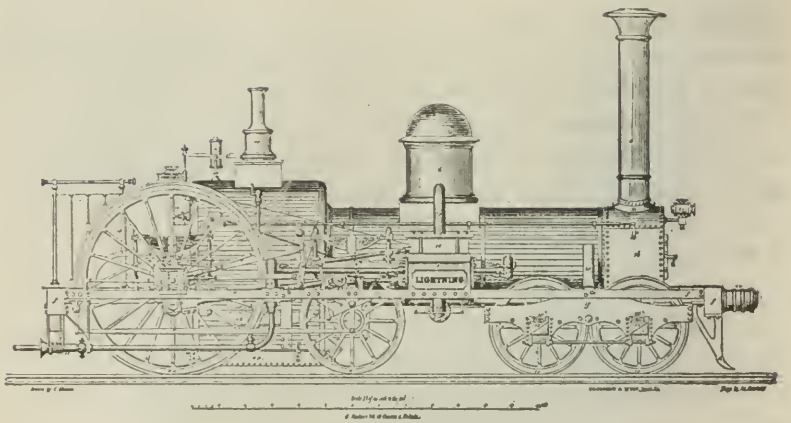
In 1849 Edward S. Norris, of Schenectady, built for the then Utica and Schenectady Railroad the *Lightning*, Crampton, with 16 inch cylinders, 22 inch stroke, and a single pair of 7-feet wheels, which ran at the rate of 60 miles an hour in the year 1850, but it only worked a short time.

Messrs. M. W. Baldwin & Co., in August, 1849, delivered to the Vermont Central Railroad an engine, the *Governor Paine*, with 17 inch cylinders, 20 inch stroke, and a pair of 6½ feet driving wheels, and subsequently sent three Crampton engines, of smaller dimensions, to the Pennsylvania Central Railroad in September, 1849.

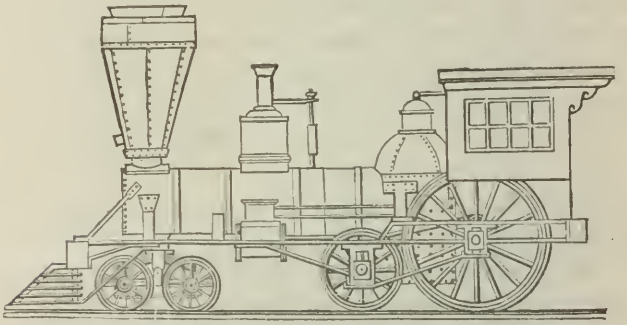
Old Ironsides, 1832.



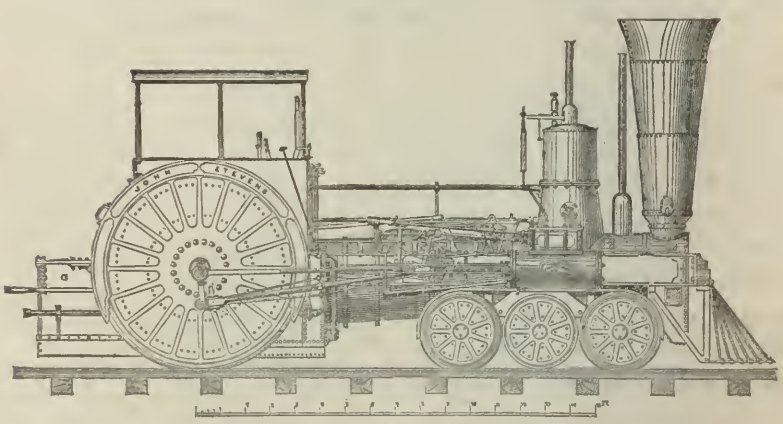
M. W. Baldwin, 1837.



Lightning, 1849.



Governor Paine, 1849.



OLD LOCOMOTIVE FOR CAMDEN & AMBOY RAILROAD.

Norris Brothers made seven engines for the Camden and Amboy Railroad, each with a single pair of 8 feet driving wheels, and a six-wheeled truck. The first of these, with 13-inch cylinders and a 34-inch stroke, was sent from the makers' shops April 17th, 1849. The next of the class had 13 × 38-inch cylinders, and were delivered Dec., 1849. The last of the series, delivered in April, 1853, had 14-inch cylinders and a 38-inch stroke. The 13-inch cylinders weighed, empty, 40,754 pounds, and loaded, 49,253 pounds. Of the weight loaded, 18,496 pounds, or about 8¼ tons, were on the driving wheels, with about 13¾ tons on the truck, making 22 tons in all. These engines had boilers 36 inches in diameter, with plates but $\frac{7}{16}$ inch thick.

In 1850 they also built two outside cylinder engines, with 14-inch cylinders, 32-inch stroke, and coupled 7-feet driving wheels, for the New York and Erie Railroad (new Erie Railway).

In the year 1849 Ross Winans, of Baltimore, built a single locomotive for the Boston and Worcester Railroad. It was for an experiment in coal-burning and constructed to burn anthracite coal. This locomotive was named the *Carroll of Carrollton*. It had one pair of 7-foot driving wheels and was intended for very high speed. It had two small steam cylinders placed on the sides of the boiler, over the bearings of the driving axle, by which the weight on the drivers could be varied from three to twelve tons.

The 7-foot drivers were cast with chilled rims and were of extremely light pattern; in fact they became broken after running six weeks. These were replaced with a set of imported wrought iron wheels, the first of the kind brought to this country.

The speed of the engine, under favorable circumstances, was one mile in sixty seconds. It was run between Albany and Boston, and the train consisted of from seven to eight cars, and made a mile a minute with ease. The engineer, J. H. Jackman, says: "Since I run her in 1849, I have traveled many thousand miles on locomotives, and have seen some high speeds made, still I have never seen the locomotive that could lay right down to it and out-run the *Carroll of Carrollton*. When I run her we made many stops, and therefore could not make better time than locomotives having smaller driving-wheels. But give me fifty or sixty miles on a clear run, and I could out-run a thunder storm if it was going our way. In those days we had no air-brakes, and to run at such high rates of speed sometimes became dangerous. I remember one instance, in the night-time, of rounding a

curve at about sixty miles per hour, when a danger signal met my view. I shut off steam and whistled down brakes, but they did not seem to check me. I whistled again; still the speed kept up. I gave the third signal for brakes, and then reversed my engine, saying to her 'Do your duty, my beauty, or in twenty seconds it is good-bye to railroading.' We came to a stand-still eighty rods from a train on the main track, having run one mile and a quarter from the place where I first discovered the red light. A locomotive engineer, to avoid trouble, must take time by the forelock—in other words, must anticipate possibilities."

Not over a dozen and a half of single engines have been made in the United States. Smaller wheels have been substituted for nearly all of these engines, from the fact that all the large-wheeled engines had small boilers, and with a single pair of driving wheels the adhesion was in all cases insufficient for the want of a proper distribution of the weight excess, as in the case of the *Carroll of Carrollton*, and, as before stated, the adhesion weight could be varied between three and twelve tons.

The present Baldwin has a similar arrangement, as before described, also the great advantage of a large boiler with ample heating and grate surface.

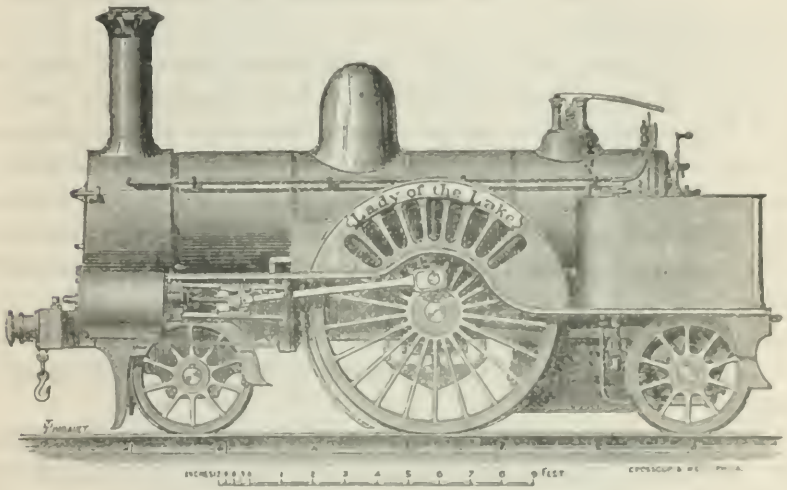
The Great Western Railway of England has seven feet gauge and was the fastest road in the world until a few years since, and its express ran regularly from Paddington (London) to Bristol, 118¼ miles, in precisely two hours, being at the rate of *fifty-nine miles* per hour.

The engines have 18-inch cylinders, 24-inch stroke, 8-feet driving wheels, and those of the largest size have 21 square feet of fire grate and a total heating surface of 1952 square feet. It has been said of them that they would evaporate from 500 to 360 cubic feet of water per hour, and are known to have worked up to quite 1000 indicated horse-power. At 60 miles an hour, 1000 horse-power would correspond to a mean effective pressure of 77·16 pounds per square inch upon the pistons (1851).

The difficulties so far for very large wheeled engines upon the narrow gauge are these: If the boiler is over the axle, the engine is top-heavy; if the boiler is beneath the axle of any pair of driving-wheels less than 12 feet in diameter, the form of the fire-box and disposal of the tubes are unsatisfactory, while, if the driving axle is behind the

fire-box (as in Norris Brothers' engines for the Camden and Amboy Railroad) hardly enough weight can be secured for adhesion. A large wheel, moreover, implies a large boiler, and not only is it difficult to provide room in a narrow-gauge engine for a very large boiler, but, beyond a certain size, there is a chance of failure under high pressures.

The following illustration represents the best average type of single express locomotives in general use on English railways for the last twenty years for the fast trains:



The above represents the "Lady of the Lake," the favorite pattern on the London and Northwestern Railway. This engine was exhibited at the International Exhibition in London, in 1862, and obtained a bronze metal for excellence of workmanship.

This engine was designed and constructed by Mr. John Ramsbottom. The following are its principal dimensions:

Area of grate in square feet, . .	14·9
Heating surface in " . .	1098.
Stroke of piston in inches, . .	24.
Diameter " " . .	10.
Diameter of driving wheels, . .	91·5
Length of wheel-base in feet, . .	15·5
Total weight of engine in working order in ton,	27·
" ". tender " " "	17·5
" " engine and tender " "	44·5

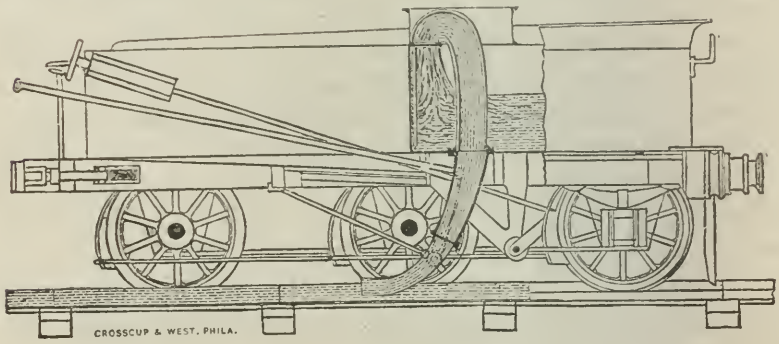
Weight on leading wheels of engine in pounds,			20,056·
"	driving wheels	" "	25,760.
"	trailing wheels	"	13,664·
Weight of engine empty		"	54,880·

The tractive force for each pound effective steam pressure per square inch on the piston this engine is capable of exerting will be

$$\frac{16^2 \times 24}{91{\cdot}5} = 67{\cdot}15 \text{ pounds.}$$

The engine *Watt*, one of the same class and build, run the special train which conveyed the Queen's messenger bearing the dispatches containing the decision of the American Government in the case of the "Trent" difficulty, in 1862, from Hollyhead to Stafford, a distance of 131 miles, without a single stoppage. The journey was made in 144 minutes, being at the rate of *fifty-four and a half miles per hour*. This remarkable run was made without stopping by the aid of Mr. Ramsbottom's "pick-up" apparatus for supplying the tender with water while running. This arrangement has been adopted by the Pennsylvania Railway, and by the use of which they have been able to reduce the size and weight of their tenders for running long distances.

The chief features of the above locomotives are that they steam well and run well, their average consumption being 22 pounds of Welsh coal per mile.



Tender "picking up" water from feed-trough when in motion.

The tender of the engine has six wheels, and weighs empty about 9½ tons; full, 17½ tons, and the load is equally distributed on the wheels.

The boilers of three engines evaporate from 150 to 180 cubic feet per hour, and in running long distances it was necessary to provide for filling the tenders with water when the train was in rapid motion. Mr. Ramsbottom conceived the idea of placing a pair of cast iron troughs, about 1500 feet long, on a level part of the road; each end about five feet had an incline of one inch in 100. The troughs are 18 inches wide and 7 inches deep, and are placed one between the rails of each line and so that the water, 5 inches deep, stands at about the level of the rails. The tenders are made to hold about 15,000 pounds, and are provided with a rising water pipe, the lower end of which is fitted with an adjustable scoop 10 inches wide at the mouth; as the scoop meets the water the effect is the same as if, the scoop being supposed at rest, the water were in motion at the velocity of the train. In either case the water must rise in the pipe, and, if permitted to do so, to a height the same as that from which a body falls, *in vacuo*, in acquiring the velocity with which the scoop and the water meet each other. At 32 feet per second, or, rather, less than 22 miles an hour, this height would be 16 feet. The height from the water trough to the top of the inlet pipe is 7½ feet, and a column of water of this height is just balanced, without delivery, at a speed of 15 miles an hour. The scoop dips two inches under the surface of the water, and at 22 miles an hour from 10,000 to 11,000 pounds are raised into the tender in 25 seconds. The delivery is practically the same at higher speeds, for although the velocity of the entering water is then greater, the time during which the apparatus is at work is diminished in the same proportion.

The Pennsylvania Railway have had a number erected on their different lines, and their advantages are, that the size and weight of the tender for running long distances may be reduced, the number of stoppages lessened and time saved. An express locomotive has thus been enabled to run the whole distance from New York to Pittsburg —438½ miles— in one continuous run of 10 hours and 5 minutes, at an average speed of *forty-three and one-half miles per hour*.

Advantage of Metallic Lubricants.—In a drying machine it was found impossible, even with the greatest care, to keep the arbors clean, so as to prevent the injury of the goods by grease-spots from the lubricating oil. The difficulty was entirely obviated by the use of *metaline* as a lubricant.—*Chron. Ind.*

C.

AN ACCOUNT OF AN EXPERIMENT MADE TO DETERMINE THE POTENTIAL AND ECONOMIC VAPORIZATION OF A BOILER IN THE ESTABLISHMENT OF MR. FREMERY, AT EUPEN.

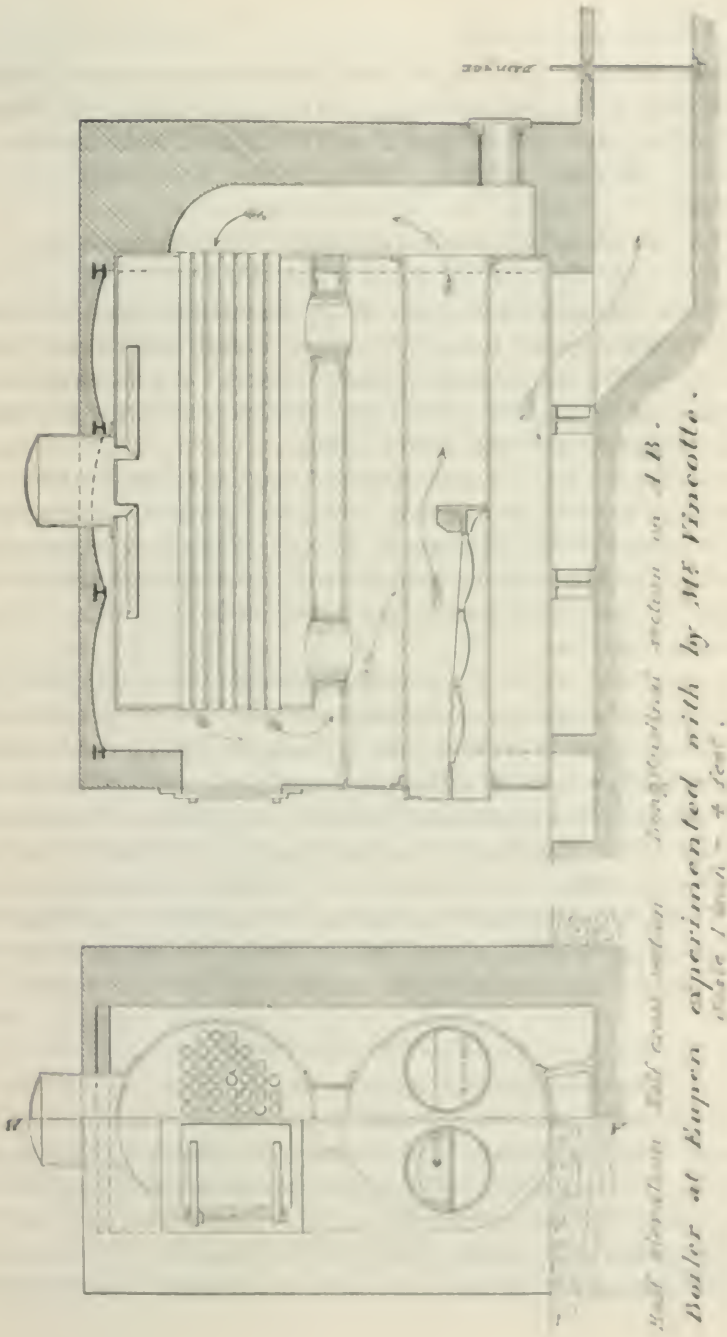
By Chief Engineer Isherwood, United States Navy.

In the appendix to a report of the discussions which took place between the engineers-in-chief of various French and Belgian "Associations for the Surveillance of Steam Boilers," at a meeting held in Brussels on the 8th, 9th and 10th of July, 1877, there is given, among other information of engineering interest, a description of an experiment made by Mr. Vincotte, Engineer-in-chief of the Brussels Association, on the 27th of February, 1878, with a boiler belonging to the establishment of Mr. Frémery at Eupen. The object of the experiment was to determine the economic and potential vaporization in this boiler, of water, with average semi-bituminous coal, under the conditions of daily use.

As the boiler was of a type not employed in the United States, and had an unusual and excessively small proportion of draught area above the bridge walls, with an unusual and excessively large proportion of heating surface to grate surface, it seemed to the writer that the data and results of the experiment, arranged and reduced in the manner adopted by the engineers of English-speaking countries, would be of value to the readers of this Journal. He has, therefore, recalculated all the quantities in English measures, and made from the French data the following account, taking nothing from the original except the observed quantities therein given, and adding his own remarks:

Boiler. (*See sketch*).

The boiler was composed of two horizontal cylindrical shells, one so placed immediately above the other that the same vertical plane passed through the longitudinal axis of each. The least space in the clear between the shells was 9 inches, and they communicated by two vertical pipes of $23\frac{5}{8}$ inches exterior diameter, whose vertical axes were also in the vertical plane passing through the longitudinal axes of the shells. One of these pipes was placed as near as practicable to the forward end



Boiler at Lupon experimented with by Mr Vincotte.

of the upper shell, and the other was similarly placed near the after end. The lower shell was 71 inches in exterior diameter and 15¼ feet in extreme length. The upper shell was 68 inches in exterior diameter and 13 feet in extreme length. The ends of the shells were flat and vertical, and the after ones of both shells were in the same vertical plane, the forward or furnace end of the lower shell projecting 2¼ feet forward of the corresponding end of the upper shell.

The two shells were entirely inclosed in brick masonry, which formed exteriorly a parallelopipedon 19 feet long, 10 feet wide, and 13 feet 4 inches high above the level of the fire-room floor. The back and side walls were 21 inches thick, the front wall was 12 inches thick, and the flat top was supported beneath by brick arches resting on iron beams of H cross-section. The least thickness of the top was 4 inches, and its greatest thickness was 8 inches.

In addition to the above brick walls, there was another which may be called the partition wall. It was entirely within the other walls, and vertical, with its after face in the vertical plane of the after ends of the two shells. This wall was six inches thick, and extended wholly across the inclosure formed by the exterior walls, and from its bottom to its top completely dividing it into two separate parts, one of which was 24 inches long in the clear, lengthwise the shells, and formed the channel for the gases of combustion in their passage from the after end of the lower to the after end of the upper shell. The remaining part was 12¾ feet long in the clear, lengthwise the shells, and formed the chamber containing the two shells. This chamber was filled with the gases of combustion which, after emerging from the forward end of the upper shell, enveloped the cylindrical parts of both.

At the bottom of the back wall was an elliptical man-hole with diameters of 14 and 18 inches, to give admission to the after chamber or channel. In the upper part of the front wall was a rectangular opening opposite the forward end of the upper shell, closed by doors, and of sufficient size to allow the sweeping of the tubes and entrance into the large chamber containing the two shells.

The two ends of the lower shell were supported on the front and partition walls of masonry, and on, equispaced between them, two iron castings. The upper shell was supported from the lower shell by their two vertical connecting pipes, and its after end also rested on the brick partition wall. Neither shell had any side supports.

The lower shell contained two horizontal cylinders extending from

one end of it to the other, and having their horizontal diameters in the plane of the horizontal diameter of the shell. These cylinders were 2·3622 feet in inside diameter and 15¼ feet in extreme length. In the forward portion of each cylinder, with a dead-plate 12 inches long between the forward end of the cylinder and the forward end of the grate, was placed a grate 6·5618 feet long, slightly inclining downwards toward the back. The bridge-wall was of fire-brick supported on an iron casting. The front end of the upper side of the grate was on a line with the horizontal diameter of the cylinder, and the back end was four inches below that line. The top of the bridge-wall was eight inches above the upper side of the grate at its back end.

The upper shell contained seventy horizontal wrought iron fire-tubes of 4 inches external and 3⅜ inches internal diameter, with an extreme length of 13 feet. These tubes are arranged, vertically, in seven rows, the horizontal diameters of those of the third row from the top being in the plane of the horizontal diameter of the shell. In the top row there are ten tubes, in the next three rows twelve each, in the next row there are ten tubes, in the next row eight, and in the lowest row six. The least spaces between the tubes, both vertically and horizontally, are 0·8 inch in the clear. The tubes are placed vertically, one immediately over the other.

The normal water-level was 3 inches above the upper row of tubes, leaving 17 inches for the greatest height of steam room in the shell.

On the top of the upper shell and at the middle of its length was placed, vertically, a cylindrical steam-drum with a curved top. The exterior diameter of this drum was 2½ feet and its extreme height above the top of the shell was 2½ feet. The steam from the shell was admitted to the drum through two perforated dry-pipes, which extended horizontally along the upper side of the shell. The steam-pipe connecting the boiler with the engine was bolted upon the top of the steam-drum.

The chamber enclosed by the brick masonry and containing the shells extended 16 inches deep below the lower side of the lower shell, and from this lower part, and at the back end of the shell, the gases of combustion were carried to the chimney through a horizontal flue of masonry lying beneath the floor of the boiler-house.

From the foregoing description it will be seen that the gases of combustion after crossing the bridge-walls in the lower shell, pass horizontally through the cylinders behind them into the channel or back

chamber of the masonry; thence they ascend vertically, enter the tubes in the upper shell, and, passing horizontally through them, debouche into the front chamber of the masonry, where they spread out and completely envelop both shells as they descend vertically to the bottom of the chamber and enter the horizontal brick flue which conducts them to the chimney. The direction of the gases is thus changed, first from horizontal to vertical, then from vertical to horizontal, and finally from horizontal to vertical, before they leave the heating surfaces; the distance they travel from the centre of the furnaces to the horizontal flue leading to the chimney is about 40 feet.

The surface of the steam room in the upper shell is steam superheating surface.

The following are the principal dimensions and proportions of the boiler, namely:

Extreme length of brickwork,	19 feet.
Extreme breadth of brickwork,	10 feet.
Extreme height of brickwork above bottom of chamber,	14½ feet.
Outer diameter of lower shell,	71 inches.
Extreme length of lower shell,	15¼ feet.
Outer diameter of upper shell,	68 inches.
Extreme length of upper shell,	13 feet.
Number of cylinders in lower shell,	2.
Inner diameter of cylinders in lower shell,	2·3622 feet.
Extreme length of cylinders in lower shell,	15¼ feet.
Number of furnaces,	2.
Breadth of grates,	2·3622 feet.
Length of grates,	6·5618 feet.
Aggregate area of grates,	31·0000 sq. ft.
Number of tubes in upper shell,	70.
Inner diameter of tubes,	3¾ inches.
Outer diameter of tubes,	4 inches.
Extreme length of tubes,	13 feet.
Aggregate cross area for draught through the tubes,	5·3689 sq. ft.
Aggregate cross area for draught over the bridge-walls,	2·8000 sq. ft.
Heating surface in furnaces to after side of bridge-walls,	63·1111 sq. ft.
Heating surface in cylinders beyond after side of bridge-walls,	107·6060 sq. ft.
Heating surface in back ends of the two shells,	28·1311 sq. ft.

Heating surface in the tubes, calculated for inside diameter,	893·3925 sq. ft.
Heating surface in the front end of the upper shell,	10·6387 sq. ft.
Heating surface in the cylindrical part of the upper shell,	141·6616 sq. ft.
Heating surface in the two pipes connecting the shells,	12·2500 sq. ft.
Heating surface in the cylindrical part of the lower shell,	249·4903 sq. ft.
Total water-heating surface in the boiler,	1506·2813 sq. ft.
Total steam superheating surface in the boiler,	75·8000 sq. ft.
Water-room in the boiler,	497·2077 cu. ft.
Steam-room in the boiler,	111·0882 cu. ft.
Square feet of water-heating surface per square foot of grate surface,	48·5897
Square feet of steam superheating surface per square foot of grate surface,	2·4451
Square feet of grate surface per square foot of draught area above bridge-walls,	11·0714
Square feet of grate surface per square foot of draught area through tubes,	5·7740

Coal.

The fuel consumed during the experiment was a good quality of semi-bituminous coal of the kind in daily use at the establishment, and it was burned just as received from the mine. A special analysis of this coal gave the following for its centesimal composition:

Hygrometric water,	1·084
Volatile matter other than water,	13·369
Coke, exclusive of ash,	76·965
Ash,	8·582
	100·000

Composition, exclusive of Hygrometric Water and Ash.

Carbon,	89·72
Hydrogen,	4·31
Oxygen,	4·20
Nitrogen,	1·00
Sulphur,	0·77
	100·00

Condition of the Boiler.

The sweeping of the boiler tubes, when in regular service, was done once in eight days. Three days before the date of the experiment they had been swept, so that they were in an average condition as regards soot. The other fire surfaces had not been swept for seven months, and must have been thickly coated with the soot due to the combustion of about 450 tons of coal in that time.

The water heating surfaces, on the water side, had not been cleaned for seven months, during which time about 3370 tons of water had been vaporized from them. This water, taken from the Vesdre river, was very pure and left no scale.

An analysis of the feed-water, previous to its entrance into the boiler, was made; and another analysis was made of the water in the boiler, which, as none of it had been blown out or removed, except by vaporization and foaming, for seven months, contained in solution nearly all the mineral matter entering with the water during that time, with the exception of what may have been precipitated as scale or sludge.

The following are the results of these two very interesting analyses, and show the centessimal composition of the waters:

	Feed-water when entering the boiler.	Feed-water in boiler after vaporization of 3370 tons.
Chloride of calcium,	0·019	1·765
Chloride of sodium,	0·005	1·766
Sulphate of soda,	0·005	0·855
Sulphate of lime,	.....	0·075
Alkaline nitrates,	traces	3·119
Organic matter,	0·025	2·170
Oxide of iron,	.....	traces
Magnesia,	.....	traces
Alumina, silica and loss,	0·001	0·010
Water,	999·945	990·240
	1000·000	1000·000

In comparing the above two analyses, there must be recollected: 1st. That the feed-water being very pure, some of the substances in solution, and notably the nitric acid, could not be determined with absolute precision. 2d. That the feed-water, as drawn from the river

Vesdre, necessarily varies slightly in composition from day to day; hence the single specimen whose analysis is first given in the above table may not, and probably does not, correspond exactly to the water whose analysis is last given, representing a mean of the feed-water during seven months. 3d. That a portion of the sulphuric acid and of the lime has disappeared to form scale and sludge. Notwithstanding the above uncertainties, these analyses are of much value from their rarity, and for the information they give in relation to the persistence of the chlorides of calcium and sodium, and of organic matter, in the fresh water of land boilers.

Experiment to ascertain the Potential and Economic Vaporization of Water by the Boiler with semi-bituminous Coal.

The experiment continued one working day of 13 consecutive hours, during which the quantity of water fed into the boiler was previously measured in a tank with great accuracy, the temperature being noted every half hour. The steam, as fast as generated, was worked off by the engine, the boiler pressure being maintained nearly uniform, and noted every half hour, also. The coal thrown into the furnaces, and the refuse therefrom, in ash, clinker, etc., were carefully weighed.

The fires, at the commencement, were started with just wood enough to light the coal, and at the end of the experiment they were burnt completely out, so that the weight of coal consumed was determined exactly. The water in the boiler at the commencement of the experiment had a less temperature than at its end, and there was, likewise, a slight variation in the quantity; these differences were carefully ascertained, and the weight of water vaporized, per tank, corrected for them.

As the day on which the experiment was made was a regular working day, intervening between two other working days, and as the fires were banked at night, the brick masonry was at about the average temperature at the commencement of the experiment, and did not require the expenditure of fuel to heat it up.

The coal was burnt at its maximum rate of combustion. The draught of the chimney was poor.

The following are the data and results of the experiment:

Boiler.	Square feet of grate surface per square foot of draught area over bridge-walls,	11·0714
	Square feet of water-heating surface per square foot of grate surface,	48·5897
Total Quantities.	Duration of the experiment in consecutive hours,	13·
	Total number of pounds of water vaporized from the mean temperature of the feed, namely 42 degrees Fahrenheit, under the mean steam pressure of 60⅔ pounds per square inch above zero,	40398·
	Total number of pounds of semi-bituminous coal consumed,	5203·
	Total number of pounds of refuse from the coal, in ash, clinker, etc.,	617·
	Total number of pounds of combustible, or gasifiable portion of the coal consumed,	4586·
	Per centum of the coal in refuse,	11·859
Rate of Combustion.	Number of pounds of coal consumed per hour,	400·2300
	Number of pounds of combustible consumed per hour,	352·7700
	Pounds of coal consumed per hour per square foot of grate,	12·9106
	Pounds of combustible consumed per hour per square foot of grate,	11·3800
	Pounds of coal consumed per hour per square foot of heating surface,	0·2657
	Pounds of combustible consumed per hour per square foot of heating surface,	0·2342
Vaporization. *Absolute.*	Number of pounds of water that would have been vaporized had it been supplied at the temperature of 100 degrees Fahrenheit, and vaporized under the standard atmospheric pressure,	43501·7525
	Number of pounds of water that would have been vaporized had it been supplied at the temperature of 212 degrees Fahrenheit, and vaporized under the standard atmospheric pressure,	48584·5248
Economic.	Pounds of water vaporized from 100° Fahrenheit by one pound of coal,	8·3609
	Pounds of water vaporized from 100° Fahrenheit by one pound of combustible,	9·4858
	Pounds of water vaporized from 212° Fahrenheit by one pound of coal,	9·3378
	Pounds of water vaporized from 212° Fahrenheit by one pound of combustible,	10·5941

In the above experiment all the conditions were combined that should have given a maximum economic result. There was a very small calorimeter above the bridge-walls, whereby the air dilution of the gases of combustion was kept at a minimum. There was only a medium rate of combustion per square foot of grate per hour, and a very slow rate of combustion per square foot of heating-surface. The ratio of water-heating surface to grate surface was very large, and the direction of the gases of combustion in their route from furnace to chimney was several times changed, so as to thoroughly mix and com-

bine them. The coal was of excellent steam-producing quality. The experiment was of such short duration that, in connection with the small per centum of refuse from the coal, there could have been but little loss from the cleaning of fires; and the radiation from the thick walls of brick masonry must have been insignificant. Yet, notwithstanding all these favorable circumstances, the economic vaporization under the atmospheric pressure was only 10·5941 pounds of water from the temperature of 212 degrees Fahrenheit per pound of the combustible or gasifiable portion of the coal. This vaporization should have been not less than 12 pounds of water, which is what has been obtained in ordinary marine boilers during much longer experiments, with poorer proportions for economy of fuel, and not better coal, the rate of combustion per hour per square foot of heating surface being about the same. Here is a loss of economic effect of not less than 11⅜ per centum, and to what is it to be attributed? Probably to the *infiltration of air through the masonry enclosing the boiler shells*. The comparatively cold external air so entering mixes with the hot gases of combustion and cools them by extracting a portion of their heat. The result is a less difference between the temperature of the mixture and that of the boiler water than would have been between the latter and the gases of combustion if unmixed, accompanied by a correspondingly less extraction of heat in equal time. Another injurious result is that the cool infiltered air, after absorbing heat from the gases of combustion, passes out with them at the same chimney temperature; the loss of heat thus caused being measured by the weight of air entering, its specific heat, and the difference of its temperature when entering and leaving the boiler. The cooling effect of the infiltering air may even check the combustion of any uncombined coal gases in the tubes and connections.

The greater the rate of combustion in a boiler set in masonry the greater will be the *absolute* quantity of air inleaked, because the greater rate of combustion is necessarily associated with a less pressure inside the masonry, that of the external air remaining constant. In fact, it is this less pressure which gives the greater draught, producing the greater rate of combustion. But, as this greater rate of combustion causes a correspondingly greater quantity of hot gases to pass through the masonry flues in equal times, the per centum of loss by the inleaked air, that is, the loss *relative* to the absolute quantity of heat in the hot

gases, will not be materially changed by change in the rate of combustion, within the limits of ordinary practice.

During the many experiments on boiler vaporization made or investigated by the writer an inferior result was always found with boilers of the same type, having the same proportions of heating to grate surface, and of calorimeter; burning the same coal at the same rate of combustion per hour per square foot of grate surface; but having their furnaces and flues in brick masonry instead of in iron shells; and just in proportion to the extent of the brick surface with which the gases of combustion were in contact.

Whenever the highest vaporization is desired from the fuel consumed at a given rate of combustion, brick settings should be wholly discarded and all parts of the boiler arranged within an iron shell; and the difference will be the greater with boilers having the least ratio of water-heating to grate surface, because in them the gases of combustion enter the chimney with the highest temperature, and the infiltered air carries off a correspondingly greater quantity of heat. Were it possible for the gases of combustion to leave the boiler with the temperature of the atmosphere, there could, of course, be no economic loss by any amount of air leaked in, for whatever heat was imparted to it on entering would be yielded up before leaving; the loss will be just in proportion to the temperature of the chimney, other things equal.

When it is considered that walls of brick masonry are easily pervious to water, there can be no difficulty in believing they are still more easily permeable by air. If brick-work be adopted for the setting of boilers, an air space of about 2 inches width should be left in the masonry, whose entire exterior should be well coated with pitch, or with a cement of mastic, to stop the inleakage of air as much as possible. This, however, the writer has never known done; and he has always observed that, after a short period of use, the masonry was more or less warped by heat, and cracked, the inleakage of air becoming correspondingly increased.

When a boiler set in brick-work is used during only a portion of the day, as is generally the case, a serious loss of fuel is experienced in heating the mass of masonry from the temperature it has when the boiler is out of use to its temperature when the boiler is in operation. This loss is measured by the weight of the masonry into the product of its specific heat by the difference of the temperatures stated.

A boiler set in brick-work will also lose more heat by radiation

than one whose gases of combustion are wholly within its shell, because the first will have a greater external surface than the second, and because the temperature of the gases of combustion are on one side of the setting, while in the case of the second the temperature in contact with the felt or other covering is only that of the contained steam, or about half as much. In either case, however, the loss by external radiation of heat is comparatively trifling.

During the experiments repeated tests were made of the steam, in order to ascertain if it carried over any water in suspension, and, if so, how much. The various methods gave reasonably accordant results, and showed that no more than $\frac{1}{3}\frac{1}{5}$ of the water in the boiler was so entrained. This quantity is not deducted from the vaporization given in the preceding table, because it was desired to have that vaporization comparable with the results of other similar experiments, and because there is great doubt of the accuracy of such determinations, which are really among the most delicate, complex and difficult in physical science, while the methods practically adopted are so very crude as not to be even approximately reliable. The proportion of water foamed over, or entrained in boilers, has been, in consequence, absurdly exaggerated.

Finally, there may be remarked that the hygrometric moisture in coal will, in general, about offset the water that may be carried over from the boiler by foaming, so that the apparent vaporization, including the entrained or foamed over water, will be about the true vaporization, exclusive of the entrained water given by the coal, exclusive of its hygrometric water.

Magnetic and Diamagnetic Elements.—The magnetic elements are N, O, Fe, Ni, Co, Mn, Pt, Os, Pd, Ir, Rh, Cr, Ti, Ce, C, K and U. The diamagnetic are H, Na, Cu, Ag, Au, Hg, Zn, Cd, Pb, Sn, P, As, Sb, Bi, S., Se, Cl, Br, I, Ti, Si. Carnelly has observed that all the elements which are found in the even series, in Mendelejeff's classification, are magnetic, while those of the odd series are diamagnetic. This result furnishes new and interesting evidence of the shrewdness of the investigators who are endeavoring to trace all chemical and physical phenomena to the action of primitive laws of motion. *Ber. d. D. Chem. Gesell.* C.

PROGRESS OF THE DEPHOSPHORIZATION OF IRON.

By F. Gautier.

Read before the Society of Civil Engineers of Paris, January 9th, 1880.
Translated by CHAS. E. BILLIN.

In my communication of July 4th, 1879,* I endeavored to show the state in which this very important question was at that time. The result of that study was that two processes were shown to have arrived at results of a certain value: the *Thomas-Gilchrist process*, by which Bessemer steel can be obtained from a pig iron as highly charged with phosphorus as the iron of Cleveland and the Moselle, and the *Krupp* or *Narjes-Bender process*, producing purified pig iron (*fontes mazée*), partially dephosphorized, and capable of being used in puddling or in the Martins-Siemens furnace.

The *Thomas-Gilchrist process*, as it has been explained in numerous communications read before the Iron and Steel Institute, at its meeting in London, and by public experiments at Eston near Middleboro', in the works of Messrs. Bolckow and Vaughan, presented the following characteristics:

Employment of a dolomitic casing, replacing the old-styled silicious lining of the converters.

Addition, at the commencement of the operation, of a mixture of lime and oxide of iron, intended to absorb the silica and phosphoric acid produced.

Continuation of the blowing beyond the ordinary stopping point in Bessemer operations.

Determination of the practical end of the dephosphorisation by a series of samples and repeated trials.

Under these conditions steel very low in carbon and containing no more than 0·15 of phosphorus has been produced from pig iron carrying 0·15; but in operating in this manner there are numerous causes of cooling. To avoid *projections* only a small charge was treated in a large converter, which augmented the loss by radiation. The addition of the oxide of iron was also a notable element in lowering the tem-

*See the Journal for February, 1880, p. 83.

perature of the operation; finally, the repeated tests at the close necessitated the loss of precious time.

In order to obviate these inconveniences, they have treated iron carrying as much as 3 per cent. of silica, the calorific power of which is very high. But this only places the problem in a deceptive circle. It is necessary to increase the basic additions in order to absorb the great quantity of silica thus produced, for there cannot be left more than 20 per cent. of silica in the slag without endangering the stability of the phosphates formed.

At the moment of the recarburation this very fluid slag, is moreover, traversed by the carbonic oxide resulting from the reaction of the carbon of the spiegel on the oxide of iron of the bath. There is then produced a partial rephosphorization of the purified metal; about a thousandth of phosphorus is added to that which had been left in the steel, and probably can only proceed from the action of the manganese of the spiegel, or of the carbonic oxide, on the phosphates of the slag. These reactions, moreover, whatever their nature, are produced with violence; the final addition should be made in several portions to avoid a sudden projection of the slag out of the converter. The metal obtained remained cold; the loss was as much as 18 to 20 per cent., that is to say, it required 1200 kilogrammes of metal, from the furnace, to obtain 1000 kilogrammes of steel ingots, whereas 1130 or 1140 suffice when the metal is pure and is submitted to ordinary treatment by the Bessemer process. The refuse from rolling attained 10 per cent. in the month of May last, and seldom was lower than 5 per cent.

Progress in England.—The first question which occupied the English engineers was to reduce the basic addition, the absorbing capacity of which was complicated with a very marked cooling action. They suppressed the oxide of iron, and forced in the limestone by an artifice analogous to that used at Neuberg in the treatment of white and mottled iron by the Bessemer process, where charcoal dust was introduced with the blast. They succeeded thus in eliminating half the phosphorus, at the same time retaining 2·5 per cent. of carbon, whereas in the old way of operating, when the carbon was reduced from 3·5 to 2·5 the diminution in the phosphorus was seldom more than 5 or 6 per cent. The suppression of the oxide of iron diminished the cooling, and protected the lining, the slag being less corrosive; but at the same time it produced obstructions at the mouth of the converter, and, to

remedy this they modified the form of the latter. They supplanted the lower demi-sphere by a right cone, decidedly truncated; the gases were then freely disengaged, and projections tumbled back into the bath without encumbering the throat.

To prevent the final explosions which resulted, as we have said, from the too quick reaction of the oxide of iron of the bath on the carbon of the spiegel or of the ferro-manganese, they called to their aid silicon. In acting on the dissolved oxide the silicon gives origin to silica, which remains in the bath and has no tendency to be projected outside.

$$3Fe^3O^4+Si=9FeO+SiO^3$$

If the silicon finds itself in presence of carbonic oxide, formed by the inevitable action which the carbon accompanying it exercises on the oxide of iron of the bath,

$$Fe^3O^4+C=3FeO+CO$$

the silicon decomposes this gas, giving origin to silica and to a deposit of carbon, which is redissolved in the metal

$$Si+3CO=3C+SiO^3$$

It will be remembered that it is this reaction which explains the formation of steel without blowholes by means of silicon.

This addition of silicon was made at Eston under the form of grey pig carrying 3 per cent. of silicon. In conformity with the preceding theory, the disengagement of carbonic oxide, which gave to the operation of overblowing a dangerous character, was entirely removed; the subsequent addition of the spiegel, destined to remove by the manganese the last traces of "red shortness," and to communicate to the metal the proper degree of carburation, was made with quiet and precision.

In order to simplify, it has been proposed in France to employ silicide of iron and manganese, which ought to have several important advantages. First, it reduces the additions to one only; and, further, in these alloys, high in silicon, the carbon is in very small proportion, not often passing 1·5 per cent., the chance of the production of carbonic oxide is reduced to a minimum; finally, the simultaneous presence of manganese and silicon ought, under an oxidizing action, to lead to the production of a very fusible silicate of iron and of manganese, and in consequence to give great homogeneity to the metal.

The trial of silicate of iron and of manganese was not made in England, except under imperfect conditions; the alloy carried but 3 per

cent. of silicon, and did not permit obtaining all the effect which one might expect.

It will be remembered that the experiments at Eston had led to the noting of a singular phenomenon: the metal dephosphorized to 0·140 was suddenly changed to 0·235 of phosphorus after the addition of the spiegel. As the spiegel contained both carbon and manganese, it is to the presence of one or the other of these substances, and to their action on the phosphate of the slag, that we must attribute this rephosphorization, which sometimes exceeded one-thousandth. The silicon, in combatting with the carbonic oxide, prevented the rephosphorization. This would seem to give reason to the opinion attributing this augmentation of phosphorus to the action of the carbonic acid on the slag.

Another means to avoid the rephosphorization was also tried at Eston. The mass of metal and slag was cooled in a ladle furnished with a stopper and an orifice at the bottom; then the metal alone was led into a second ladle, where, protected from the contact of the slag, the introduction of the spiegel was made.

This arrangement succeeded well enough, but it was renounced, owing to the additional cooling which resulted from it, and which it was easy to foresee.

Finally, in order to comply with certain criticisms expressed in regard to the accuracy of the diagrams representing the relative oxidation of the different elements which accompany the iron in the metal treated, Mr. Richards submitted to the meeting of the Iron and Steel Institute, at Liverpool, the results of samples taken every three minutes after the commencement of the operation.

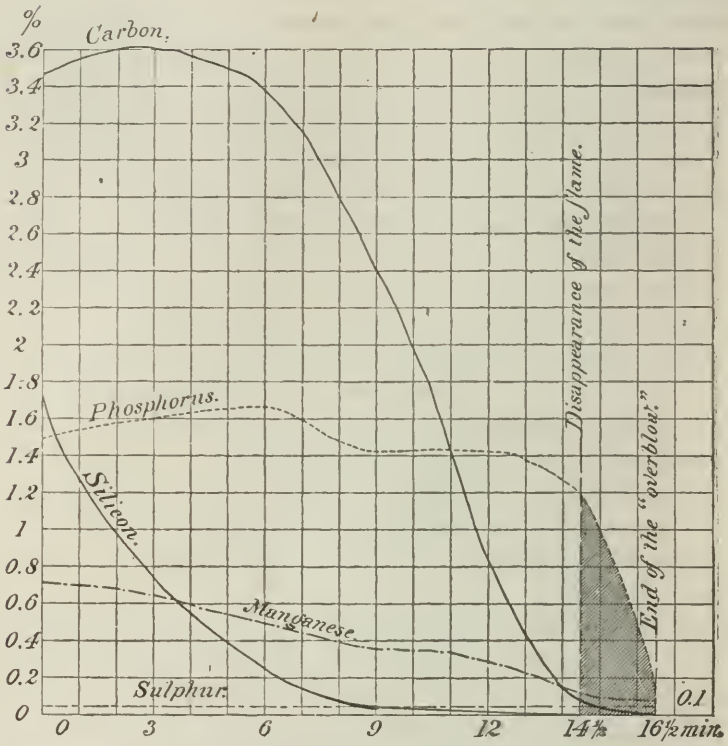
Metal.

Time,	0	3′	6′	9′	12′	14′ 30″	16′ 30″
Phosphorus,	1·5	1·6	1·63	1·13	1·12	1·2	0·08
Carbon,	3·5	3·6	3·4	2·4	0·9	0·075	
Silicon,	1·7	0·8	0·28	0·05	0·01	0	0
Manganese,	0·7	0·62	0·55	0·37	0·28	0·13	0·1
Sulphur,	0·05	0·05	0·05	0·05	0·05	0·05	0·05

Corresponding Slags.

Time,	3′	6′	9′	12′	14′ 30″	16′ 30″	18′ 30″
Silica,	32·60	42·60	36·00	35·60	33·00	15·60	16·60
Phosphoric acid,	0·60	0·15	1·60	2·61	5·66	15·06	16·03
Iron,	5·65	2·	4·60	4·80	6.15	10·45	11·35

The following diagram shows these results graphically.



En résumé, the improvements introduced in England do not modify the nature of the first material employed. This always remains a very gray and silicious iron, comparatively difficult and costly to produce.

Progress in Westphalia.—The most important modifications introduced in the working of the Thomas-Gilchrist process reach us from the works of Hörde. The director, M. Massenez, and the engineer, M. Pink, have given, at the matallurgical meeting at Dusseldorff (General-Versammlung des technischen Vereins für Eisenhüttenwesen), held Deccember 15th, 1879, very detailed descriptions, which we have every reason to believe exact.

Dephosphorization was attempted September 22d, 1879, and from the first, M. Massenez (to give his own figurative language) "declared an obstinate war to the silicon, in order to make a compact of friendship with the phosphorus."

He asserts that with "white" iron, having 0·5 of silicon, 2·5 of carbon, and more than 2·0 of phosphorus, to have succeeded in making steel having ·03 to ·06 of phosphorus.

Below are given some numerical details communicated by the works of Hörde:

	Hörde Iron.		Luxemburg Iron.
	Grey.	White.	
Silicon, . .	1·50 to 2·85	0·36	1·218
Phosphorus, .	1·30 to 1·01	1·70	1·726
Sulphur, . .	0·01 to 0·07	0·16	0·173
Manganese, .	1·30 to 0·65	1·30	0·197
Carbon, . .	3·60 to 3·34	2·30	3·122

Operation No. 67.

Grey iron of Hörde, . . .	1200 kil.
White iron " . .	1500 "
Steel scrap, . . .	500 "
Spiegel, . . .	210 "
	3410
Yield, . . .	3087

	Phosphorus.	Carbon.	Sulphur.	Manganese.	Silicon.
Pig iron, . .	1·04	2·58	0·22	1·35	1·08
After 11′ 45″, .	0·82	0·08	0·19	0·39	0·09
After 100″ of overblowing,	0·08	0·06	0·15	0·39	0·007
15″ later, . .	0·045	0·04	0·14	0·37	0·005
Final product, .	0·06	0·28	0·067	0·46	0·002

Operation No. 68.

Grey iron of Hörde, . . .	1200 kil.
White iron, . . .	1500 "
Scraps, ...	600 "
Spiegel, . . .	210 "
	3510 "
Yield, . . .	3126 "

	Phosphorus.	Carbon.	Sulphur.	Manganese.	Silicon.
Pig iron,	0·96	2·82	0·16	1·04	0·45
After 14′,	0·70	0·09	0·16	0·40	0·02
After 110″ of overblowing,	0·09	0·085	0·15	0·33	0·003
15″ later,	0·05	0·081	0·09	0·29	.....
Final product,	0·06	0·26	0·009	0·31	.....

Operation No. 69.

Grey iron,	900 kil.
White iron,	1800 "
Scraps,	600 "
Spiegel,	210 "
	3510 "
Yield,	3156 "

	Phosphorus.	Carbon.	Sulphur.	Manganese.	Silicon.
Pig iron,	1·04	0·73	0·25	1·27	0·72
After 12′,	0·74	0·08	0·18	0·45	0·14
After 120″ of overblowing,	0·06	0·07	0·12	0·19	0·004
Final product,	0·06	0·24	0·063	0·40	.....

The total of these three consecutive runs gives:

Material treated,	10·430	1·120
Yield,	9·310	1·000
Loss,	1·120	·120

The total weight of the slag would be 2250 kilogrammes.

Final Slags.

	(*a*).	(*b*).	(*c*).
Silica,	9·50	13·81	11·10
Phosphoric acid,	9·76	7·38	12·43
Magnetic oxide, Fe^3O^4,	9·28	6·92	11·25
Protoxide of iron,	.....	1·41	.....
Protoxide of manganese,	6·16	6·20	4·40
Lime,	59·35	57·85	50·21
Magnesia,	5·01	6·93	9·84
Sulphuret of calcium,	0·87	0·22	1·15
Alumina,	traces	traces	traces
Totals,	99·93	100·72	100·38

The slags (*a*) and (*b*) belong to several operations; the analysis (*c*) is the average from the three operations, 67, 68 and 69.

The fact of there being only traces of alumina should be noticed. Before this, at Eston, with bricks containing 10 per cent. of alumina, there was only found 1·3 per cent. in the slag; it seems, then, that the alumina has less tendency than the lime and magnesia to be attacked under the double action of the silica and phosphoric acid.

The metal, tried for tensile strength, gave:

	Breaking load in kilogrammes per millim. sq.	Elongation. Per cent.	Contraction. Per cent.
Operation No. 67, .	. 50·1	20·6	44·8
" 68, .	53·5	22·0	47·0
" 69, .	. 54·3	19·2	42·0

The length of the test pieces is not indicated.

At Hörde they have also made metal for sheets, giving 39 kilogrammes of resistance per millimetre square, and 70 per cent. of contraction.

It is to be regretted that the figures relative to still more phosphoric runs have not been communicated.

That which characterizes these very interesting experiments is the substitution of phosphorus for the silicon, as the calorific element in the Bessemer process. Until the present we only knew two elements, the combustion of which could develop and maintain the temperature necessary to the operation —*silicon* and *manganese*—the first having a calorific power of 7830, according to recent researches of Troost and Hautefeuille, and the second of 8000, according to the same authors. The engineers of Hörde present to us a third substance—*phosphorus*—the combustion of which will be, under equal pressure, an element of heat at least as intense as silicon or manganese. According to Laplace and Lavoisier, the calorific power of phosphorus, in changing to phosphoric acid, would be 7500 calories, and if we compare the products of the combustion, phosphoric acid, on the one part, silica, oxide of manganese, on the other, leaving to the contact of the bath all the heat produced, we will no longer be astonished at this new role played by the phosphorus.

They even assert that the works of Hörde have specified, in buying pig iron for Bessemer use, that it shall contain at least 2 per cent. of phosphorus, not more than 1 per cent. of silica, nor 0·2 of sulphur.

They also speak of the manufacture of special alloys of iron and phosphorus destined to introduce the quantity of this last substance necessary to the operation (M. Gautier presented to the meeting specimens of phosphuret of iron containing 22 per cent. of phosphorus. It is silver white, iridescent upon fracture, and very difficult to attack with acids).

The substitution of phosphorus for the silicon has the effect of making the phosphates predominate in the slag; these are much less corrosive than the silicates, and the wear and tear of the lining is less.

The operation at Hörde is conducted in a manner notably different from that which we have seen in the works of Bolckow-Vaughan.

As soon as a charge is finished they put in the converter the addition of lime for the next charge, about 20 per cent. of the weight of the iron to be treated. They add coke and coal, in large pieces, raise the converter and blow. The hydrate of lime is decomposed, and the last traces of carbonic oxide are expelled. They thus diminish the projections and partial explosions, which were frequent with the old method of working, and overcome in part the cooling which accompanied the cold additions made at the commencement. It is not until later that they charge the pig metal.

On account of the feeble amount of silicon which the iron contains, and probably, also, owing to the presence of a small amount of coke from the preliminary heating, one perceives immediately the yellow ray of sodium, and the spectrum is not long in expanding.

The operation is notably shortened, and lasts from 8 to 15 minutes at most. Observation shows that the oxidation of the phosphorus does not commence until after the elimination of the greater part of the silicon, and after the combustion of a considerable proportion of carbon. Nevertheless, the dephosphorization was more rapid than at Eston, and there is also no need for continuing the overblowing for as long a time. It varied between 100 and 240 seconds; but ordinarily 100 to 150 seconds suffices. When the nature of the metal to be treated is known in advance, the operation can be governed by the length of time after the disappearance of the spectrum and the cessation of the flame. A small ingot is then taken by means of a ladle which is plunged into the converter. This is hammered, cooled and broken. The appearance of the break is sufficiently characteristic to indicate the increase (of phosphorus?) given by overblowing. The engineers of Hörde claim to find in the aspect of the fumes an evi-

dence of the practical end of dephosphorization. When there is, so to speak, no more phosphorus, the oxygen of the air exerts itself entirely on the iron and manganese, and there are then seen abundant fumes of a very peculiar intensity, proceeding from the oxides of iron and manganese. There were no projections during the operation, which is surprising for nearly white iron. It is necessary, from this point of view, to believe that the phosphorus acts in the same protective way as the silicon, and prevents the reaction of the oxide of iron on the carbon from becoming too violent.

The operation is terminated by the addition of spiegel. Neither explosions nor rephosphorization of the dephosphorized metal are noticed. There is something here which demands an explanation, for the engineers of Hörde do not seem to have recourse to silicious additions, and one cannot well see how the carbon of the spiegel would react less tumultuously here, on the oxide of iron of the bath, because the pig iron was less silicious and contained more phosphorus.

The lining, of which we have not yet spoken, for it presents no new character, is made with dolomitic bricks, having the following composition:

	Before baking.	After baking.
Silica, . . .	2·14	9·43
Iron and alumina, .	0·62	4·13
Carbonate of lime, . .	55·05	.....
Carbonate of magnesia, .	42·50	.....

These bricks, like those which they used at Eston, are long and difficult to bake. 36 hours for kindling, an excessively quick fire during 100 hours, and slow cooling of 100 hours, are necessary. The dolomite of Rühr, which they employ, is neither rare nor costly, but 5 tons of coal are necessary to bake 1 ton of bricks.

These basic linings resist for a hundred operations; this is already a splendid result; but the converters, with ordinary silicious lining, support a thousand operations before requiring renewal, which is generally caused more by accumulations than by corrosion.

The bottoms are made (en pisé) with the débris of basic bricks, agglomerated with mineral pitch. They employ no tuyeres, but pierce holes in the mass, which are necessary for the introduction of the air. These bottoms will resist fifteen operations, about half the life of ordinary silicious bottoms. Their deterioration would seem to be due more to a physical action than to a chemical decomposition. Perhaps,

in increasing the blast pressure, the shocks from the liquid mass would be diminished and agitations quieted, as has been observed in Sweden.

The loss, according to the engineers of Hörde, is not greater than in their ordinary operations with pig iron from hematites, 10 to 11 per cent.; whereas with the silicious iron of Luxemburg, in the same basic converters, the loss reached 15 per cent. M. Massenez gives the following explanation: 1 part of silicon requires at least 2 parts of iron to form a silicate; the less silicon there is to scorify, the less will be the loss of iron.

This seems probable, for it has been long noticed that silicious iron leads to a greater loss in puddling. Further, the phosphoric acid, the state of which in the slag is a subject of much dispute, combines, in part at least, with the lime and magnesia, and is not so greedy for iron as the silica.

The sulphur of the iron seems to be eliminated to two-thirds. What becomes of it? It is held that the manganese facilitates desulphurization. It is necessary to admit, then, that it forms some sulphuret of manganese or of calcium in solution in the slag, a point which is not yet elucidated, and which presents great importance in the future of the process; for, if it is easier and more economical to produce "white" iron, it is to be feared, also, that it is much less sulphurous than grey and silicious iron obtained from the same burden.

The fact that phosphorus is sought for in the iron, or added during the operation, as the case may be, in order to facilitate its after elimination, is certainly very interesting, and seems even paradoxical.

(To be continued.)

American Laureates of the French Academy.—At the last public annual session of the French Academy the Lalande prize was awarded to Prof. C. F. H. Peters, of Clinton, N. Y., for his planetary discoveries. The total number of asteroids discovered by him is 43, eight of which were added to the list during the past year. At the the same sitting, the Valz prize was awarded to M. Trouvelot, of Cambridge, Mass., whose magnificent drawings of the planets Mars, Jupiter and Saturn represent the telescopic appearances with remarkable accuracy and furnish an excellent basis for the minute study of the superficial phenomena of these planets.—*Comptes Rendus.* C.

The INVOLUTE of the CIRCUMFERENCE of a CIRCLE.

By L. D'Auria.

Professor of Applied Mechanics, former Engineer of the Military Topographic Institute in Italy, etc.

The relation between the circumference of a circle and its involute, as well as the relation between the area of a circle and the area generated by the tangent line in describing the involute of the same circle, once occurred to the writer in a problem of mechanics, and fruitlessly he searched in many authors of differential and integral calculus in use to find them; so that he was compelled to determine these relations by himself. The following is the method he used:

Let L be the length of the involute of an arc of circle of radius R, and φ degrees. If we imagine the circular arc divided in a certain number, n, of equal parts, each part will evidently contain $\frac{\varphi}{n}$ degrees; and if we imagine drawn the tangent lines at the extremities of these n arcs of circle, the angle formed by two consecutive tangents will be also $\frac{\varphi}{n}$ degrees.

Now, the length of one of the n circular arcs is

$$\frac{\pi\,\varphi\,R}{180.n};$$

and the length of the successive tangent lines drawn at the extremities of the n circular arcs, and confined between the involute and the evolute, are evidently

$$o,\ \frac{\pi\,\varphi\,R}{180.n},\ \frac{2\pi\varphi R}{180.n},\ \frac{3\pi\varphi R}{180.n},\ \ldots\ldots\ \frac{n\pi\varphi R}{180.n} \qquad (1)$$

When n is a very great number, the sum of the n successive arcs of involute confined between the $n+1$ tangents (1), will be equal with approximation to the sum of n circular arcs, each containing $\frac{\varphi}{n}$ degrees, described successively by radii equal to the tangents (1).

The sum of these n circular arcs is

$$\frac{\pi^2\,\varphi^2\,R}{180^2.n^2}+\frac{2\pi^2\,\varphi^2\,R}{180^2.n^2}+\frac{3\pi^2\,\varphi^2\,R}{180^2.n^2}+\ldots.+\frac{n\pi^2\,\varphi^2\,R}{180^2.n^2};$$

therefore approximately will be

$$L=\frac{\pi^2\,\varphi^2\,R}{180^2.n^2}\,(1+2+3+\ldots+n)=\frac{\pi^2\,\varphi^2\,R}{180^2.n^2}\times\frac{n(n+1)}{2};\quad\text{or}$$

$$L=\frac{\pi^2\,\varphi^2\,R}{2.180^2}\left(1+\frac{1}{n}\right).$$

This formula, with the supposition of $n=\infty$, becomes exact, and will be

$$L=\frac{\pi^2\,\varphi^2\,R}{2.180^2}. \qquad (2)$$

When $\varphi=360^\circ$

$$L=2\,\pi^2\,R\,;$$

or denoting by C the circumference of the circle (evolute)

$$L=\pi\,C. \qquad (3)$$

The formula (2) holds good, also, when the involute of the whole circumference being described by a thread developing from it, this operation is continued, so that the rotation of the tangent line will exceed 360°.

Substituting in equation (2) successively

$$\varphi=360,\ \varphi=2\times 369,\ \varphi=3\times 360,\ \ldots\ \varphi=N\times 360,$$

the corresponding values of L will be

$$\pi C,\ 3\pi C,\ 5\pi C,\ 7\pi C,\ \ldots.\ (2N-1)\pi C.$$

These values form a series proportional to the series of the odd natural numbers 1, 3, 5, 7, 9, 11, ...

Denoting by A the area generated by the tangent line in describing the involute of a circular arc of radius R and φ degrees, conserving the other denotations (n being a very great number) the area A will be, with approximation, equal to the sum of n circular sectors, each containing $\frac{\varphi}{n}$ degrees, described successively by radii equal to the tangents (1). This sum is

$$\frac{\pi^3\varphi^3R^2}{2\cdot 180^3\cdot n^3}+\frac{2^2\cdot\pi^3\varphi^3R^2}{2\cdot 180^3\cdot n^3}+\frac{3^2\cdot\pi^3\varphi^3R^2}{2\cdot 180^3\cdot n^3}+\ldots.+\frac{n^2\pi^3\varphi^3R^2}{2\cdot 180^3\cdot n^3};$$

therefore with approximation will be

$$A=\frac{\pi^3\varphi^3R^2}{2\cdot 180^3n^3}\,(1^2+2^2+3^2+\ldots+n^2)=\frac{\pi^3\varphi^3R^2}{2\cdot 180^3n^3}\left(\frac{n^3}{3}+\frac{n^2}{2}+\frac{n}{6}\right)$$

$$\therefore \qquad A = \frac{\pi^3 \varphi^3 R^2}{2 \cdot 180^3} \left(1 + \frac{1}{2n} + \frac{1}{6n^2}\right)$$

This formula, with supposition of $n = \infty$ becomes exact, and will be

$$A = \frac{\pi^3 \varphi^3 R^2}{6 \cdot 180^3}$$

When $\varphi = 360°$

$$A = \frac{4}{3} \pi^3 R^2; \text{ or } A = \frac{1}{3} \pi \cdot C^2.$$

This last formula and formula (3) can easily be memorized, and although they are not in use in ordinary problems of mechanics, it would be not superfluous to introduce them in some manual of engineering.

A NEW PENDULUM SUSPENSION.

By Louis H. Spellier.

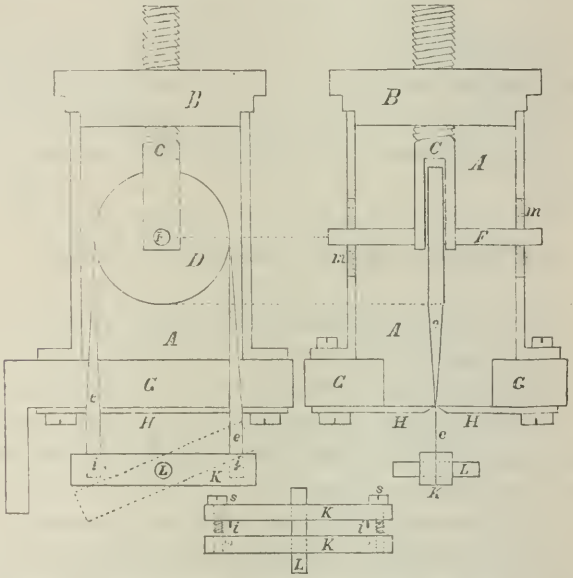
The time-keeping qualities of a clock are almost entirely dependent upon the correctness of the pendulum, and ever since its introduction as a medium to divide time into equal intervals, it has received the very greatest attention accordingly.

As it is the object of the compensation of the pendulum to keep its centre of gravity regardless of change of temperature, at an equal distance from its centre of oscillation, so its suspension should allow only its re-occurring oscillations to follow the track of a straight line and to move in a straight plane only.

The chief if not the only condition to arrive at this result is to give the suspending spring an even tension. Unless this condition is complied with the oscillating pendulum will be accompanied by the well known wabbling side motions which so greatly interfere with its correctness.

Pendulums have been suspended on one as well as on two springs, the latter of which is almost entirely abandoned. None of the suspensions so far had a contrivance which would automatically adjust the tension of the suspending spring, and so with mathematical certainty avoid the wabbling motion alluded to. The author claims to have succeeded in constructing such a suspension. It solves the problem perfectly.

A is a tube screwed on to the supporting base *G*. *B* is a round piece covering and fitting into the tube *A*. Through the centre of *B* goes a screw-threaded spindle *C*, which bears on its lower end, between a fork-like cut, a pulley *D*. *F* is the pin on which the pulley turns and extends through opposite cuts in the tube, to prevent *C* and *D* from turning when *B* is turned to lower or raise the pulley *D*.



Over the pulley the suspending spring *e* lies, and its two ends are fastened between the two bars *KK*. The two plates *HH* are screwed against the under part of *G*, and just far enough apart to allow the ends of the spring to extend laterally through the slit they form.

If now the pendulum hangs on the *L* its weight will bear equally on either side of the spring by means of the pulley, and adjust its tension automatically.

How perfectly that suspension adjusts the tension can be seen if we bring the bars *KK* into the position shown by the dotted lines. Even this abnormal position will not interfere with the pendulum in performing its oscillations in a true plane. While with other suspensions it would be impossible to avoid the wabbling motions if *K* and *H* would vary the least from being parallel.

THE PUDDLING PROCESS, PAST AND PRESENT.

By Percival Roberts, Jr.

Read before the American Institute of Mining Engineers

It may seem necessary to offer an apology for presenting for consideration a process which is conspicuous by its absence in the literature of the Institute, and which may be thought by some to belong to the past in metallurgy, and to have been already superseded. But the large capital invested in puddling calls for a careful consideration of the question whether the time has certainly arrived when the puddling furnace must be replaced by the converter and open-hearth furnace. May there not still be a place for puddled iron alongside of molten iron and steel, and is not the improvement of the puddling process itself worthy the attention of engineers equally with the Bessemer and open-hearth processes?

The changes involved in the conversion of pig iron into wrought iron are well understood and need only be briefly alluded to. The patent of Henry Cort bears the date of 1784. Since that time the improvements in the process have mainly consisted in the replacement of sand by iron bottoms by Samuel Baldwyn Rogers in 1818, and the still more recent substitution of iron oxide for the refractory materials used for the sides and bridge of the hearth, which distinguishes the wet or boiling process from the dry or puddling process. Chemically, the process consists in the removal of the metalloids from the pig iron, a result effected mainly by the iron oxide. Silicon is first oxidized, then the phosphorus, and finally the carbon. The silicic and phosphoric acids produced pass into the cinder and the carbonic oxide burns as it escapes from the bath of metal.

It is interesting in this connection to note the effect of temperature on the removal of the phosphorus from the iron. As is well known, no phosphorus is eliminated under the oxidizing influences prevailing in the Bessemer converter, while from 70 to 80 per cent. is removed in puddling. But we find, if in working cold short irons the temperature of the furnace is much increased towards the end of the process, that a considerable amount of the phosphoric acid is deoxidized and phosphorus again combines with the iron. This reverse process

is aided by a siliceous cinder arising either from the use of a very siliceous pig iron, or of an over-siliceous ore for fix. The fact which has been known for some time that only a basic cinder can retain phosphoric acid has given rise to the "basic lining" which now attracts so much attention in the Bessemer process. For the conditions affecting the removal of phosphorus from pig iron I would refer to the careful and complete experiments of I. Lowthian Bell, in England.

Notwithstanding the recent progress in the metallurge of iron the puddling process is essentially what it was three-quarters of a century ago—laborious, crude and unsatisfactory. The attempts at improvement in the process may be classified under two heads: 1. economy of labor; and 2. economy of fuel.

Increase of yield and improvement of quality are so intimately connected with both of these two classes that it is not easy to consider one apart from the other.

1. Economy of Labor.

For the successful accomplishment of the operation of puddling it is necessary to bring the molten metal into contact with the solid oxides by agitation effected either by human or mechanical agency upon a stationary hearth, or by giving motion to the whole body of the furnace. One of the first attempts for lessening the labor of the puddler is recorded in a drawing at Dowlais which has been traced back to the year 1834. It is a reverberatory furnace with a revolving hearth, driven with a vertical shaft by bevel gearing. Whether this machine was ever used I do not know, but it is of interest as showing that most of subsequent improvements are not new in principle. Coming to more recent times, we have the Richardson process of blowing air into the molten bath through a tubular rabble. The advantages claimed for this method are that it hastens the boil, reduces the labors, and produces a tough metal of uniform and high quality. After the iron has come to a boil the rabble is withdrawn and the working continued in the ordinary manner. I believe this process has never been used in this country and but sparingly in England.

Morgan's puddling machine consists of a reverberatory furnace of the usual form, which has an opening in the roof through which a vertical shaft is lowered with a horizontal arm. The shaft is set in motion by suitable machinery, and the arm revolves in the furnace, doing away with the labor of the puddler and helper until the heat is

ready for balling, when the shaft and arm are withdrawn, the opening in the roof closed, and the balling proceeded with in the usual manner. The wear and tear connected with this method must be enormous, and the results, I should think, not very satisfactory.

Griffith's and Whitham's devices are similar in idea, but different in mechanical details. Their object is to give an oscillating movement to a rabble of the ordinary shape by means of machinery, the puddler or helper merely guiding the rabble. The balling is accomplished in all cases by hand labor. None of the above-mentioned improvements do away with the skilled workman, but merely lessen the laborious work of the early stages of the heat, which requires brute force rather than experience.

In a work by Kohn upon the *Manufacture of Iron and Steel* will be found more detailed statements concerning these processes. That any of them has proved satisfactory I question. One of the imperfections common to them all is the difficulty of keeping the raw iron from gathering in the crevices of the fix and settling on the bottom and in the corners of the furnace into which the rabble does not enter, leaving the furnace at the conclusion of the heat in a very dirty condition. We all know the importance of a thorough working of iron in the jambs of a furnace, as it is there that the metal begins to gather when coming to nature, requiring careful working for good results. Another serious objection which may be advanced against these processes is, that they require the same skilled workmen to operate them as are needed for the old style of hand puddling. No increase in the number of heats is obtained, for the men, instead of encouraging experiments, look upon them with great distrust as inimical to their best interest, and when a workman and his tools do not agree good results cannot be expected.

About 1867 a change in the direction of improvement took place, and it was reserved for an American, Samuel Danks, to have the boldness to propose an entire revolution in the puddling process. The Danks furnace was the first rotary furnace to be put into successful operation, although its success was not assured until many improvements and alterations were made upon the original designs.

In England this same idea was elaborated, and several machines were brought out differing in details. The one of most novel construction was the Godfrey-Howson furnace, which had but one opening into which the heat enters and the products of combustion

escape, a blowpipe on a large scale being substituted for the ordinary fireplace. Later, in this country, we find a rotary furnace designed by the Edgemoor Iron Company, of Wilmington, Del., worthy of mention from the fact that this company is at present equipping their works with these furnaces, which would seem to indicate great confidence upon the part of the proprietors in the success of the rotary process.

2. Economy of Fuel.

In the utilization of coal for puddling two methods are employed. The one in almost universal use, where coal is directly burned on the grate of the furnace, is irrational and wasteful. The other method, consisting in the conversion of the coal into combustible gases, which are burned on the hearth of the furnace, though more economical and rational, is but seldom used.

The attempts which have been made to improve the old system may be divided into two classes: First, those having for their object the prevention of smoke by feeding the coal below the surface of the fire, which is always kept bright. The mechanical devices for accomplishing this object are found in the Frisbie & Sweet furnaces. The system has not come into general use. An objection in the case of coal forming clinkers is, that the clinkers are forced to the top of the fire. Second, those having for their object the utilization of the volatile matters of the coal by a partial coking of the coal before it reaches the fire. This is effected by the employment of a separate magazine in connection with the fireplace. The gases from the coal are caused to pass over the fire and are there burned. Of this variety of furnace may be mentioned the Wilson furnace, and of more recent date the Price furnace, which has given very good results.

When we consider, however, the cost of introducing these improved furnaces, and the trouble and annoyance of teaching workmen to use them, it is evident that we might just as well go a step further and introduce the gas system in its entirety. The great advantages to be gained in the use of gas in puddling are well known. We may distinguish here two systems, the continuous-acting furnace, of which Swindell's furnace is an example, and the well-known Siemens regenerative furnace.

Of the use of water-gas in the place of the ordinary generator-gas it is too soon to speak, but reference may be made in passing to the astonishing results said to have been obtained at Washington by the

Gill process, with gas containing as high as 75 per cent. of combustible gases, which we take *cum grano salis.*

What, let us now ask, is the present state of the puddling process, and what relation does its welded product sustain to the fused product of the Bessemer converter and the Siemens furnace? Will steel supplant iron?

In a paper on the Separation of Phosphorus from Pig Iron, read before the Iron and Steel Institute of Great Britain in 1878, by I. Lowthian Bell, occurs the following:

"The elimination of this metalloid from pig iron is, doubtless, a subject of great interest and importance to British smelters, having regard to the fact that nearly five-sixths of the metal obtained from their native ores contains so much of this impurity as to unfit it for the manufacture of steel, that form of iron which bids fair to supersede, in a great measure, the product of the puddling furnace."

If phosphorus cannot be removed, the question is easily settled; the production of steel is a limited one; and in the future, as at present, it will be made from the highest grades of our pig irons, and be used for certain special purposes, such as rails, etc., for which it has shown its great superiority over iron.

But, no doubt, many will at once say: phosphorus can be removed, the Thomas & Gilchrist process, with its basic lining, has overcome this difficulty. That phosphorus has been removed experimentally there can be no question; that it has been expelled successfully, from a commercial point of view, is open to doubt. Of the three processes established for its elimination, the Bell, the Krupp, and the Thomas & Gilchrist processes, the second has, from an economical standpoint, produced the best results.

There are some points in regard to all of them which, in the published results of experiments, have not been very fully touched upon, though they are of great importance. Is the increased cost of working greater than the difference in price between inferior brands of pig iron and those suitable for steel-making? This is, of course, a secondary consideration if the demand for such pig exceeds the supply, but it will be of vital importance if the reverse is the case. Is the removal of phosphorus uniform or does it vary, giving us results differing from day to day? What is the percentage of bad blooms made by these processes as compared with the usual method of working? How uniform is the quality of the final product as furnished to the con-

sumer? It will, perhaps, be said that sufficient experience has not yet been obtained to answer these questions, but until they are disposed of we must be very cautious in accepting the announcement made by inventors or operators to the effect that success has been achieved. Granted that a method of dephosphorization may be established upon a commercially successful basis (and present indications seem to point to such a conclusion), what will be the resulting product, and how well will it be fitted for its intended uses?

In advocating the use of high qualities of steel, and enumerating the advantages to be gained by employing it, the fact is frequently lost sight of that this superior metal is made from the highest grades of pig, obtained with the greatest care from the purest ores, and that the succeeding processes are worked out with the aid of the most improved plant. The metal is followed through all details of manipulation with the most thorough inspection and rigid chemical and mechanical tests. Material thus obtained is compared with wrought iron made from anything and everything. No chemist mixes the charge or analyzes the product, but a puddler is left to guard the interests at the most vital stage of the process. It is his aim to produce the greatest weight, with the least labor, in as short a time as possible, and with such work no one can blame him. It is not astonishing that under such conditions iron is so much inferior in its physical qualities to steel. Even taking the same grade of pig metal for the manufacture of wrought iron as is now used for steel, the mild grades of the latter suitable for structural purposes will, no doubt, give higher results by mechanical tests, but the difference between the two will not be as great as many are apt to think.

On the other hand, if in the future, by means of dephosphorizing processes, we shall use all sorts of pig iron for steel, shall we not introduce a dangerous element of uncertainty into its manufacture which we do not have to deal with at present? When it is considered how very slight a change in the percentage of some foreign substance may produce a considerable variation in the quality of steel, uniformity in a metal derived from such impure raw materials must be difficult to attain. The homogeneous nature of steel, as compared with the many-pieced structure of iron, is claimed as one of its advantages. Homogeneity in steel may be a cause of weakness, and the lack of homogeneity in iron a source of strength. A steel bloom, to all external appearance perfect, may be within entirely bad, either

from piping in the moulds, or from other causes of a similar nature. Chemical analysis will not show this defect, and a bar produced from the same, although sound as far as can be seen, may fail in service suddenly and without warning. On the other hand, the possibility of a wholly bad iron bar diminishes just in proportion as the number of pieces in the pile from which it is made increases.

For a material for structural purposes the term uniformity should take the place of homogeneity. A material exposed to abrasion, such as a rail receives, requires the latter quality, but one subjected to strains of compression and extension, tension and bending, wants uniformity more than any other property. If one bad member is contained in a structure the strength and homogeneity of the whole is of no avail. For many purposes in construction steel may be used to very good advantage, notably for members liable to wear and parts running in bearings. But whenever it is applied in parts of varying outline, where sudden changes in form take place, planes of weakness are developed at all those points at which anything like a corner occurs, unless large fillets are used and great care is taken. It must not be forgotten that the structures hitherto erected of steel, have been, as it were, experimental, and have therefore been put up with the closest inspection and caution. If it should be generally adopted, this same care could not be exercised unless an entire revolution in existing modes of manufacture takes place. The rough handling which iron for structural use receives in manipulation would be fatal to steel. Existing plant and methods of working must be abolished, and workmen be educated in the proper handling of the new products.

Looking upon the above objections as a few of the more important ones yet to be met before a more general use of steel can take place, it will be apparent that its substitution for wrought iron will be very slow and gradual. The puddler and his furnace yet have many years before them. No one could regret it more than the writer. No other process in iron metallurgy requires so much work per ton of metal produced. It seems absurd to think that the labor of two men for ten hours is necessary to produce a ton of wrought iron, and that for one ton of pig iron used one ton of coal is consumed! It is not worth while to consider those methods which aim merely to lighten but do not do away with the labor of the puddler. They may have some advantages, but they will never come into general use. What is needed is a method which is governed by intelligence, but which requires only

ordinary labor for its working. The rotary furnace process is the only one which at present aims at this result, but its complete success is open to doubt. The wear and tear of the complicated mechanism and revolving surfaces is a source of expense, and the lining is composed of a material not well calculated to resist heat. The quality of the iron, however, is good, and counterbalances many of the attending disadvantages, although it will not, as was at one time hoped, answer for making bars without weld. It must be cut and piled as ordinary iron, or the work upon it will not suffice for good results.

We are now in the midst of an epoch of uncertainty; a few years more and the success or failure of steel to supplant wrought iron will be established beyond a doubt. Its success depends upon the results which shall be obtained from the working of all grades of pig iron; and its failure is certain if uniform quality cannot be produced. For the present, therefore, the system of puddling must continue as of old; but every ironmaster, not only of this but of other countries, will most gladly welcome the process, whether it be of steel or of iron, which shall do away with the weary toil of so many thousands, and usher in a brighter and a better era than could ever be accomplished by the puddling process as invented by Henry Cort.

Relation of Spectral Rays to the Constitution of Nebulæ.—Ch. Fievey has made the spectral rays of hydrogen and of nitrogen the subject of a special careful investigation. By attaching to the spectroscope a contrivance which enables him to regulate at will the quantity of light received, he observed that the spectrum of hydrogen was modified and simplified in proportion as the brilliancy diminished. The H line first disappeared, then C, and finally only F was left. It is well to remember that the F line is the only one of the hydrogen lines which has been observed, in a large number of nebulæ that have been examined by the spectroscope. The spectrum of nitrogen gave results similar to that of hydrogen. It is, therefore, not strange that we should meet, in nebulous spectra, only the rays which are most persistent in diminished light. Such rays may suffice to establish the presence of the body to which they belong, and the disappearance of the others may be explained by their extinction in traversing the intervening spaces.—*Bull. de l'Acad. Belg.* C.

SLAG CEMENT.

We have on several occasions directed attention in this Journal to the very important question of the satisfactory utilization of the slag produced from blast furnaces. In past years this product has been accumulating to a vast extent, and the ironmasters have been put to enormous expense and inconvenience in providing places of deposit for many millions of tons of this, until very recent date, comparatively useless article. It is true that in some few instances it has been employed in filling up shallow bays, and even for making roads in the immediate vicinity of the works where it is produced, and where other more suitable material cannot be conveniently supplied, but for both these purposes the demand has been extremely limited, and in the vast majority of cases it has been got rid of as so much rubbish.

One very important use to which blast furnace slag has been proposed to be put has been in the production of bricks for building purposes, and for this application Mr. Charles Wood, the manager of the Tees Iron Works, Middlesbrough, obtained a patent in the year 1873, and full description of the processes employed by Mr. Wood have appeared in our columns. More recently we had occasion to speak of a patent obtained by Mr. Frederick Ransome (who for nearly forty years past has been prominently before the scientific world as the inventor of several ingenious and valuable processes for the manufacture of artificial stone) for the production of an eminently hydraulic cement, in which the slag sand from the blast furnaces forms a conspicuous and very important feature, and of this cement we have now something more to say. Good Portland cement, which now enters so largely into the construction of all hydraulic and substantial building operations, is, as our readers are aware, a compound of silicate of lime and alumina, and contains about:

	Per cent.
Lime,	62
Silica,	22
Alumina,	8
Oxide iron,	3
Potash, soda, magnesia, etc.,	5
	100

This composition is generally obtained by intimately mixing chalk and clay, this mixture being burnt at a very high temperature into an extremely hard clinker, which is subsequently ground to a fine powder. Mr. Ransome having been applied to, to produce a cement possessing the strength and valuable hydraulic properties of Portland cement, was not slow to appreciate, and avail himself of the valuable results obtainable by a combination of the slag sand from the blast furnaces with an additional quantity of lime. He at once commenced a series of experiments, and, as we stated in this Journal in December, 1879, he succeeded in producing a cement of a most delicate color, possessing extraordinary hydraulic powers, and acquiring great strength, increasing with age. Thus at three days it was stronger than Portland cement at seven days; in seven days it was stronger than Portland cement at three months; at fifteen days it was stronger than Portland cement at twelve months; and at twenty-eight days it was stronger than Portland cement at seven years. The foregoing results were obtained by mixing the slag sand, supplied by the Tees Iron Company, with the white chalk of Essex, in the proportion of about 1 ton of slag sand to $1\frac{3}{4}$ tons of chalk, and subsequently burning the same in an ordinary cement kiln. The composition of the slag sand above alluded to was, as stated in our former notice, found by analysis to be:

Silica,	38·25
Alumina,	22·19
Lime,	31·56
Magnesia,	4·14
Calcic sulphide,	2·95
Protoxide iron, etc.,	·91

Mr. Ransome has, however, ascertained that he is able to obtain a still stronger cement by the employment of slags containing a higher percentage of alumina. It was long since discovered and reported by M. E. Frémy and MM. Rivot and Chatony in their admirable works on cements, "That aluminate of lime is the principal hydraulic agent in cements." M. E. Frémy attributes the setting of a hydraulic cement to two chemical actions: (1) To the hydration of aluminates of lime, and (2) to the action of hydrate of lime upon the silicate of lime and the silicate of alumina and lime which exists in all cements, and in this case act as puzzolanas. The results arrived at by Mr. Ransome fully corroborate these views, and by attaching full importance to the presence of alumina, Mr. Ransome has, as we have mentioned,

succeeded in greatly increasing the strength of the new cement. Samples which we have seen show remarkable hardness and closeness, and the material in fact promises to be an exceedingly valuable one. By the employment of blast furnace slag sand the great proportion of the expense involved in the production of the clinkers used in the ordinary process of manufacturing cement is avoided; the cost of fuel and expense of grinding being hence reduced, while a useful application is found for what has been until recently a waste product. The Ransome cement, as made from the blast furnace slag sand without the admixture of any coloring matter, is of an exceedingly pleasant tint, while any desired color can be given to it as desired by the addition of suitable coloring materials. Altogether, Mr. Ransome may be said to have created a new branch of industry of value alike to engineers, architects, ironmasters, and cement makers, and we are not surprised to learn that he is meeting with the co-operation of many of our leading men interested both in our iron and cement manufacture.—*Engineering.*

Influence of Capillarity upon Dyeing.—Gustav Engel has conducted an interesting series of experiments upon animal and vegetable substances, with a view to ascertain the principles involved in dyeing. Microscopical examination of infusorial earth showed that the coloring matter was attached solely to the interior of capillary tubes. The experiments all agreed in proving that the facility of absorbing and retaining dyes depends almost entirely upon physical structure and especially on capillarity.—*Bull. de la Soc. de Mulhouse.* C.

Phosphorescence of the Glow-worm.—Jousset de Bellesme has repeated the experiments of Matteucci upon the glow-worm with some precautions which lead him to more satisfactory results. He removed the cephalic ganglia so as to destroy all voluntary phosphorescence, and substituted the passage of a moderate electric current through the body, or in the luminous organ, thus producing a brilliant phosphorescence. When the insect thus prepared was plunged into carbonic acid, or into either of the inert gases nitrogen and hydrogen, the electric excitement produced no light. His investigations lead him to regard phosphorescence as a general property of protoplasm, consisting in a disengagement of phosphuretted hydrogen.—*Comptes Rendus.* C.

Variations of Gaseous Compressibility.—E. H. Amagat describes his experiments with various gases under extraordinary pressures. He finds that the greatest variations from the action of hydrogen are found in the gases which are nearest liquefaction. This is shown very clearly by the curves of formene and ethylene. Nitrogen and carbonic oxide show much smaller variations; those of oxygen are more considerable. The variations of air are intermediate between those of its constituent gases; the oxygen and nitrogen seem to be compressed separately, as if they were entirely independent of each other. The minimum ordinate of air is situated between the analogous ordinates of oxygen and nitrogen and sensibly nearer that of the latter gas.—*Ann. de Chim. et de Phys.* C.

Measurement of High Pressures.—In Cailletet's experiments upon the liquefaction of gases he used a manometer which enabled him to measure pressures of 1500 atmospheres with a probable error of not more than one-half of one per cent. It was constructed upon a principle which was suggested by M. Marcel Deprez. When water is compressed under a piston which is perfectly cylindrical and which works in a cavity drilled in a metallic mass, so that the annular space is very small, the water will escape only very slowly through the narrow passage. With this apparatus, which works without friction, it will be possible, by loading the valve, to weigh the pressures which tend to raise it. The apparatus which he used consisted of a cube of melted steel of 0·2 metres (7·9 inches) in thickness, in which a cylindrical aperture is drilled to receive the steel piston, and adjusted so precisely that the breadth of the annular space between them is less than $\frac{1}{2000}$ of a millimetre (·0002 inch). A very sensitive lever receives at one of its extremities weights which exert upon the valve pressures that can be exactly measured. He placed under the piston a piece of gold-beater's skin, which offers an inappreciable resistance to flexure and which prevents the escape of water through the valve. In order to ascertain the precise moment when the piston is raised, he fixed upon the frame an insulated copper screw, against which the lever struck at the very moment when it was moved by the piston. The contact gave passage to a current which sounded an electrical bell. He found by a great variety of experiments that the indications for different pressures were very uniform.—*Ann. de Chim. et de Phys.* C.

French Railways.—The new railways now under contract will increase the French lines from 22,193 kilometres (13,790·73 miles) to 40,000 kilometres (24,855 miles). Most of the work will be done under the superintendence of the government agencies, and the lines will be managed under state supervision, but not at government expense. The freight tariff is lower than in any other country except Belgium.—*Chron. Ind.* C.

New Use of Nickel.—Nickel is more infusible than iron, more malleable, more ductile, tougher, and not affected by atmospheric influences. M. Fleitmann has found that when melted it absorbs some carbonic acid, and if a small quantity of magnesium is then added the metal becomes remarkably ductile and malleable. It can be drawn out into very fine wire or beaten into extremely thin leaves, and can be readily welded either to nickel or to iron.—*Chron. Ind.* C.

The Longest Geodetic Arc.—By the joint labors of Spanish and French engineers, under the direction of Ibañez and Perrier, science possesses the measurement of a meridional arc of 27°, the longest that has yet been measured on the earth and projected astronomically in the heavens. Biot and Arago, on their return from Spain, anticipated the possibility of such an undertaking, if the revival of Spanish civilization should ever open the way, and their dream has been realized, after ten years' work, in an arc which extends from the northernmost of the Shetland isles, in lat. 61°, to the Saharan desert, in lat. 34°, covering nearly one-third of a quadrant.—*Comptes Rendus.* C.

Coal in India.—Theodore W. H. Hughes begins a paper on the coal fields of India by saying: "It will doubtless surprise many to learn that both in the superficial extent of its coal measures and associated rocks, and in the actual amount of its coal, India is surpassed by few countries, and that with respect to the size of some of the seams it stands pre-eminent in the history of mining." Even the United States cannot boast of seams 100 feet, 120 feet and 160 feet thick, like some that occur in Bengal. He calculates that the coal fields of India cover 35,000 square miles, and according to estimates drawn up by Dr. Oldman there cannot be less than 20,000,000,000 tons of coal in the Empire. Much of the material, however, is of an inferior quality and fit only for very rough use.—*L'Ingen. Univ.* C.

New Theory of the Formation of Hail.—Colladon supposes that the heavy rains and the hail-storms which follow them produce, by the very effect of their fall, a vertical wind due to the air which they draw from the upper regions of the atmosphere by their own friction. This vertical wind, which extends from the cloud to the ground, necessarily leaves behind it a partial vacuum, which produces an influx of air during the whole continuance of the storm.—*Les Mondes.* C.

Relation of Gases to Pressure, Volume and Temperature.—At the last meeting of the German naturalists and physicians Clausius read a paper upon Mariotte's law, in which he gave the ratio

$$p = R\frac{T}{v-a} - \frac{c}{T(v+\beta)^2}$$

p representing the pressure, v the volume, T the absolute temperature, R, a, β and c constants depending upon the nature of the gas. He found, by a series of experiments at different temperatures with carbonic acid gas, that the results were expressed much more closely by his formula than by that of van der Waals.—*Ann. d. Phys. u. Chem.* C.

Superficial Vibrations. — Prof. Francis-Honoré Lechat has studied this subject, both theoretically and experimentally, and finds that his mathematical theory is completely confirmed by his experiments. If, for a given form of surface, we compare the durations of the periods at different depths, these periods are found to increase with the depth, but in a diminishing ratio, so that at a moderate depth the duration ceases to vary. This result agrees both with the theory of Lagrange and with that of Poisson. But the limiting depth depends upon the form of surface, the depth diminishing with the complication of the form. This agrees with the theory of Poisson, but is not indicated by that of Lagrange. Lagrange and Poisson are both in error as to the relation between the duration of the period and the form of the surface for any fixed depth. Their errors seem to have arisen from supposing that the molecules of the free surface remain constantly upon the surface during the vibration. We must therefore conclude that this hypothesis is not legitimate, and that it is necessary to admit, with the brothers Weber, that the molecules of the surface quit it in order to penetrate into the mass of the liquid.—*Ann. de Chim. et de Phys.* C.

Newly-discovered Nervous Energy.—During the past year Dr. Brown-Sequard has often noticed that the irritation produced by a transverse section of the base of the brain produces opposite effects upon the nerves which are before and behind the section. Following the lead of these indications, he finds that some parts of the nervous system are able, when irritated, to produce a sudden notable augmentation of the properties, or of the motion or sensitive activities, of other parts of the system.—*Comptes Rendus.* C.

Metallic Varnish.—Some years ago workmen at Natal observed that many of the *Euphorbiaceæ*, when cut by iron or steel, leave on the blade a coating of adhesive gum, which it is very difficult to remove, and which is an effectual safeguard against rust. The gum can be dissolved in alcohol and applied as a varnish to the hulls of vessels or other metallic surfaces. The alcohol soon evaporates, and leaves the gum in close adhesion. It is, moreover, so bitter that the white ants will not attack any object coated by it. *Les Mondes.* C.

Artificial Wines.—The ravages of the *phylloxera* have greatly increased the demand for "artificial wines" and brandies, or those made from raisins. E. Martin undertakes the defence of these products, and says that chemical analysis can show no difference between them and those which are made from fresh grapes. He states, however, that it is better to add an equal portion of fresh grapes, so as to quicken the fermentation which has been rendered sluggish by drying. When this is done, he defies the most skillful connoisseur to detect two specimens of artificial wines among eight others of natural wines. —*Chron. Indust.* C.

Book Notices

Linkages; the different Forms and Uses of Articulated Links. By J. D. C. De Roos. Translated from "Revue Universelle des Mines," and reprinted from "Van Nostrand's Magazine" No. 47.

On the Motion of a Solid in a Fluid; and the Vibrations of Liquid Spheroids. By Thomas Craig, Ph.D. Reprinted from "Van Nostrand's Magazine," No. 49.

These two numbers of Van Nostrand's Science Series contain important discussions of their respective subjects. The treatise on link-

ages gives a very good summary of the knowledge upon that subject six years ago, and it contains much information that will be new to most American readers. The book might, however, have been made much more valuable if the translator had compiled, from the JOURNAL OF THE FRANKLIN INSTITUTE and other sources, some of the more recent discussions by Prof. Marks and others.

Dr. Craig's volume gives a brief account of several of the great problems of hydrodynamics, the figure of the earth, flow through an orifice, motion of a solid in a fluid, etc. He has greatly added to the value of his own labors by giving full references to many of the most important memoirs, from which further information may be obtained in regard to the various points that are treated. In some of the problems he has simplified the necessary integrations by introducing curvilinear co-ordinates, and transforming the different equations of fluid motion by the aid of such systems of co-ordinates. Some idea of the extent of his research in preparing the volume may be formed from the following partial list of authors whose works are cited. Todhunter, Dirichlet, Maxwell, Kirchhoff and Boltzmann, Bjerknes, Laplace, Resal, Lionville, Mayer, Sir Wm. Thomson, Tait, Riemann. With the exception of a few typographical inaccuracies the work is worthy of great commendation, containing as it does, a very complete discussion of important problems which are continually recurring in many departments of modern scientific investigation. C.

WATER ANALYSIS FOR SANITARY PURPOSES; with Hints for the Interpretation of Results. By E. Frankland, Ph.D. 12mo. Philadelphia: Presley Blakiston. 1880.

In this volume the distinguished Vice President of the Institute of Chemistry of Great Britain gives us the leading particulars in the analysis of water, stating that the exhaustive chemical examination of it is one of the most tedious and troublesome operations a chemist is called upon to perform, from the great multiplicity of separate substances which may be present either in solution or in suspension, the minute proportion in which they may exist and the difficulties attending their exact determination; but if the object is only to ascertain the suitability of the water for domestic or manufacturing purposes, many of the most tedious of the operations may be omitted.

The work is divided into two parts and an appendix. In Part 1 the various steps in water analysis without gas apparatus are given, and in Part 2 the processes requiring it. In the Appendix are mentioned the various reagents employed in water analysis, while useful tables, etc., are given. We have been much pleased with this work and the clear style in which it is written by its learned author, who is, evidently, a master of this subject. N.

A Practical Treatise on Natural and Artificial Concrete: its Varieties and Constructive Adaptations. By Henry Reid. New edition. 8vo. London: E. & F. N. Spon. 1879.

The great importance of this subject and the success of the author's previous work, published more than ten years ago, is the reason of the appearance of this handsome volume, in which the most recent knowledge is collected and the whole worthily treated by one who has devoted much attention to it. In tracing the progress of scientific concrete making, the author claims to have shown that the success achieved by these prosperous industries has been due to the steady adherance of their several selectors to accurate rules, which should guide all manufacturers, and due acknowledgment is made of the valuable information he has obtained from General Gilmore's treatise on "Coignet Beton," as regards the industry in the United States. The table of contents and a full index show the care with which the work has been prepared, while the colored plates and numerous illustrations throughout the text prove that the publishers have spared no expense in making this volume worthy of being considered a practical treatise on a subject destined to become of the greatest importance with the advances that are now being made. We cordially commend the volume to the attention of our readers. N.

Health and Healthy Homes; a Guide to Domestic Hygiene. By George Wilson, M.D. 12mo. Philadelphia: Presley Blakiston. 1880.

This useful little volume, by the author of the "Handbook of Hygiene and Sanitary Science," will be welcome in many a home, and we trust will find numerous readers, as a concise and practical treatise on a subject upon which information is all-important. The author

has wisely avoided technicalities, writing as he does for all classes of readers, and has performed his task in so careful a way as to leave little to his American editor, Dr. J. G. Richardson, to add, excepting a few additions respecting matters wherein variations of climate, sanitary regulations, etc., call for notice. We have been most favorably impressed with the chapters on the "Causes of Disease" and "Food and Diet." Under the head of intemperance he does not hesitate to express his opinion that the moderate use of alcoholic stimulants has not been proved to be detrimental to the health of persons partaking of them daily, but who are careful never to exceed a certain limit; but, on the contrary, that they often prove a valuable aid to digestion, making the wheels of life to run more smoothly without in any way injuring its machinery, an opinion in which temperance people will be sure to differ, although as he adds civilization itself exhibits a strange unison with the consumption of alcohol.

The book, like all Mr. Blakiston's publications, is tastefully got up and of course well printed. N.

Franklin Institute.

Hall of the Institute, June 16th, 1880.

The stated meeting was called to order at 8 o'clock P.M., the President, Mr. William P. Tatham, in the chair.

There were present 104 members and 17 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that 19 persons were elected members of the Institute at their last meeting.

The Secretary reported the following donations to the Library:

Report of the Board of Commissioners of the Cincinnati Industrial Exposition. 1879. From the Board.

Papers relating to the Foreign Relations of the United States. From the Department of State, Washington.

Engravings of Ancient Cathedrals, etc. By John Coney. London. From Dr. Isaac Norris.

Sixth Annual Report of the New Jersey State Board of Agriculture for the year 1878. From the Board.

Life and Work of Joseph Henry. By F. L. Popé.

San Francisco Chronicle: its History, etc. 1879.
From the Office.

Memoirs of the Yellow Fever. By Wm. Currie. Philadelphia, 1798. From Dr. Isaac Norris.

Annual Report of the Water Department of the City of Philadelphia for 1879. From the Chief Engineer.

Eighth Annual Report of the Board of Directors of the Zoological Society of Philadelphia. 1880. From the Society.

Project for a Technological Institute and Museum of Useful Arts in Philadelphia. 1875. From J. W. Nystrom.

Annual Reports of the Wisconsin Geological Survey for 1878 and 1879. By T. C. Chamberlain. From the Survey.

Photometric Researches. By Wm. H. Pickering.
From the Author.

Cambridge Boiler Explosion. Boston, 1878.
From A. Williams & Co.

Engine and Boiler Insurance Company. Chief Engineer's Report. 1880. From the Company.

First and Second Annual Reports of Bureau of Statistics of Labor and Industries of New Jersey. 1878–9. From the Bureau.

Report of J. H. Comstock upon Cotton Insects. Washington. 1879. From the Department of Agriculture.

Statistical Abstract of the United States. 1879. Washington.
From the Treasury Department.

Bulletin No. 4 United States Entomological Commission.

Introduction to the Study of the Sign Language. By G. Mallery. Washington, 1880. From the Department of the Interior.

Annual Report of the Secretary of the American Iron and Steel Association. 1880. From the Association.

Handbok för beräkning och byggnad af Turbiner och Turbinpumpar. By C. A. Angström. Stockholm, 1880. 2 vols.
From the Author.

Congressional Record of March 4th, 1879; containing Memorial Exercises in Honor of Joseph Henry.

American Ephemeris and Nautical Almanac for 1879.
From Wm. Charlton, Jr., U. S. R. M.

Transactions of the Connecticut Academy of Arts and Sciences. Vol. 1, Part 2; Vol. 2, Parts 1 and 2; Vol. 3, Parts 1 and 2.
From the Academy.

Report of the Great Trigonometrical Survey of India. Vol. 5.
From the Viceroy and Governor-General of India.

Report of the Board of Commissioners of the State Survey of New York. 1877.
Report of the New York State Survey for 1878.
From J. T. Gardner, Director.

Reports P_2, Q_2, Q_3 of Second Geological Survey of Pennsylvania.
From the Board.

Specifications and Drawings of British Patents. Vols. 2 to 21. January to May, 1879. And Disclaimers, etc. No. 2378 of 1868; No. 1823 of 1869; No. 1491 of 1870; Nos. 2044 and 3217 of 1875; No. 3875 of 1876; Nos. 1110, 2909, 4169 and 4783 of 1877; No. 1715 of 1878, and No. 763 of 1879.
From the Commissioners of Patents.

Reports of Commissioner of Education for 1875 and 1876. Washington, 1876 and 1877. And
Record of Officers and Men of New Jersey in the Civil War, 1861 to 1865. In 2 vols. Trenton, 1876.
From W. S. Cooley, Philadelphia.

Mr. W. Barnet Le Van exhibited drawings of some express locomotives, and read a short paper describing them. His paper also described the tender built to pick up water from a trough while the train is in motion.*

Mr. Le Van's prophecy, at the last meeting, that in a few years trains would be run between New York and Philadelphia in sixty minutes, having been criticised, he read a short addition to his paper on the subject of imperfect railroads, showing that one-half of the average resistance to traction on level railways is due to imperfections in the condition of the road bed, and also that if all the railroads were level only one-half of the present engine power would be required, with a corresponding reduction of working expenses. He had no doubt that road beds would be so perfected as to permit the high rates of speed he had propheeied, and he quoted from eminent engineers to show that they looked upon a perfect railroad as a possibility of the future. The advances already made give promise that we will go still further in the same direction.

Mr. Hector Orr inquired whether the increased speed of railway trains led to an increased loss of life by accident.

* See page 21.

Mr. Le Van said that he had not studied the statistics of the subject, and therefore could not answer the question specifically, but his impression was that there would be no increased danger, the greater speed going along with improvements in road beds, etc. He believed that there was less loss of life now on the Pennsylvania Railroad than before the fast trains were introduced.

The question was further discussed by Messrs. Cooper and Nystrom.

Mr. Theodore T. Woodruff, inventor of the parlor sleeping car, described, with the aid of illustrations, his steam motor for cultivation of the soil—an immense machine, estimated to weigh, with water and fuel, 51,500 pounds, and, as arranged for plowing, estimated to run 132 feet per minute. In the drawings the machine was represented with 15 plows, each designed to turn 14 inches wide, so that the machine would prepare ground for a width of 17 feet 6 inches at the rate mentioned above. Among the peculiarities of the machine is the system of truss bracing, to secure rigidity, and the use of track drums, with sun and planet motion of cog wheels on a rack, whereby it is designed to have the machine lay down and take up the track on which it runs. The track drums are broad-faced and carry tracks on which the machine rests. They are set in motion by an annular rack, in which the driving wheels gear. The motor is guided as well as driven by steam, and the plows are adjustable (within limits) to any desired depth. The motor may also be adapted for ditching, grinding, threshing, sawing, etc.

The President inquired whether the machine described had ever been built.

Mr. Woodruff replied that it had not, but he had made all the calculations as to friction, etc., over dirt roads and fresh earth.

Mr. Cartwright inquired how much land the machine was calculated to plow, and Mr. Woodruff replied three and a fraction acres in one hour.

The Secretary then presented his report on inventions and novelties which had been sent to the Institute for exhibition.

Among these was the Rhyston wangle, a machine designed to iron clothes without heat. The clothes to be smoothed are wrapped on a roller in a linen cloth, and are then rocked to and fro, under pressure, on a concave table. The Rhyston machine for doing this work is compactly built, comparatively small and very easily operated.

Mangles of various kinds are largely used in Europe, but in this coun-

try have not as yet been introduced to any great extent, except in hotels and large laundries. They undertake to do by pressure alone what is done with the sad iron by heat and pressure, and are used for everything except starched and ruffled garments. Where much ironing has to be done, mangles prove economical, as they save a great expenditure for fuel. They are also economical of time, a large roll of articles to be ironed being pressed at once and in a few minutes.

Jewett's patent water filter, which combines a removable and cleansable filter, with a charcoal filter and a porcelain-lined reservoir for filtered water and ice. By the combination of the two filters the grosser impurities are kept from accumulating in the filtering bed.

Wooden pulleys, with taper sleeve fastenings, from the Taper Sleeve Pulley Works, Erie, Pa., were then described. The web of the pulley is constructed of segmental pieces, in each of which the grain is in a radial line from centre to circumference. The rim is constructed by building up a series of rings on either side of the web, and the completed pulleys are afterwards turned true and finished with shellac to protect them from the weather. The taper sleeve coupling and pulley fastenings are constructed on the same principle. Two ring-nuts, to be screwed upon a shell having a taper bore, smallest in the centre, and two split sleeves, comprise the parts. The ends of the shafts to be united are slightly dovetailed, and, being put in position in the shell, the split sleeves are driven into position by the screw nuts, and serve as wedges to keep the shafting united in the shell. The taper sleeve pulley fastening is identical in principle. The absence of set screws or similar devices for uniting shafting does away with dangerous projections to catch belts or clothing, and leaves the shaft uninjured by the cutting of key ways, etc.

I. P. Wendell's lubricating journal box for cars was shown in model. These boxes are now being tried experimentally on cars of the Union and Tenth and Eleventh Street Passenger Railway Companies. The motion of the car on its springs is utilized to pump up from the journal box the oil used to lubricate the axles, the oil being used over and over again until the box needs replenishing. The amount of oil to be pumped in successive jets is regulated by enlarging or diminishing the orifice through which it is thrown upon the axle. The apparatus is quite simple, and adds very little to the cost of the boxes.

Weston's differential pulley blocks, both direct and geared, were

shown. By their use a man can lift from 2000 to 5000 pounds, and they have the advantage over the ordinary pulley block that when you let go the chain the load still remains suspended, and it can be lowered only by pulling on the opposite side of the slack chain. In hoisting, the chain is taken up on the larger and paid off from the smaller of the wheels, the effect on the load being due to the difference in their diameters. In geared pulleys an extra wheel is added.

Several different styles of Brown's staple binder, for inserting wire staples in business and law papers, etc., were exhibited, and Partridge's patent pencil pointer.

Robinson's combination brace, wrench and hand vise was shown; also the Enterprise Manufacturing Company's fruit press, and a new style of carriage wrench, through the kindness of Truman & Shaw.

Alfred Wilkinson's metallic piston rod packing is made wholly of metal, and consists of cylindrical socket cases having annular anterior recesses, on which the periphery of the preceding one is made to fit so as to form separate and independent compartments. In the compartments are fitted Babbit metal rings, divided in only one place and arranged to break joints. These Babbit rings are encircled by a brass ring, cut in one place only and also arranged to break joints. The rings are held in contact with the piston rod by means of band springs. The whole is readily placed in the ordinary stuffing box and held there by the usual gland, the latter being used without alteration. It is claimed that the packing is entirely free from steam pressure, works with little or no friction on the rod, and secures an absolutely steam-tight joint.

Haines' patent self-locking hook was shown and described. The two arms are connected by a collar having on one of its sides ratchet teeth, which are engaged by similar teeth on the shank of the hook, which is capable of turning, the weight of the traces, etc., holding it securely locked.

Mr. W. W. Warner, representing the International Chemical Company, of New York, exhibited samples of dress goods treated with neptunite, or "fibre mail," to make them waterproof, while at the same time permitting the circulation of air through them. The goods shown were silks, satins and velvets, some of them of delicate shades. They were unchanged in appearance by the application of neptunite, which is a new product of rubber, but perfectly resisted the action of water, as Mr. Warner showed by sprinkling water upon them.

In answer to queries from members of the Institute Mr. Warner said that the preparation did not add materially to the weight of the article treated; that it did not appear to wear off; that it was not affected by the heat of the sun or exposure to the weather, and that after it had been subjected to a high temperature there was no known solvent for neptunite. It is originally treated with naphtha, as a solvent, but after being applied naphtha fails to have any effect on it. Goods treated with it can be washed with soap without injuring them or removing the waterproof covering from the fibres. It is suitable for underwear as well as for dress goods, as it is pervious to air. The question of cost has not been determined, but Mr. Warner estimated that at the outside it would not add more than twenty to twenty-five per cent. to the retail cost of silks, satins, etc., that is to say, a silk now selling for $4 a yard, retail, might cost, say $5 a yard after having been made waterproof with this preparation.

As to the manner of treating the goods, the neptunite could be applied at any stage of the process of manufacture or after the goods had been finished. The company preferred to treat silk in the yarn before being manufactured, as the neptunite gives it greater body. He believed that goods thus made waterproof were also less combustible than ordinary goods, and also that the neptunite protected them from moths, etc.

Mr. Warner was asked whether the process was a patented or a secret one. He replied that it was a little of both; it was patented and the process kept as secret as any patented process can be.

In reply to the question as to who invented neptunite he said it was Mr. D. M. Lamb, of New York, but that gentleman had become a lion since his invention.

The Secretary said that he thought neptunite would prove very valuable in making waterproof the cloth bindings of books, which are liable to irremediable injury by water. Mr. Warner said that it would undoubtedly protect them.

The consideration of the resolutions offered by Prof. Frazer at the April meeting for the appointment of a committee of chemists to examine and report upon a disputed question of analysis was, in the absence of that gentleman, postponed until the next meeting in September.

There being no further business, the Institute adjourned.

ISAAC NORRIS, M.D., *Secretary.*

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THE LIMITATIONS OF THE STEAM ENGINE.

By WILLIAM DENNIS MARKS, Ph.B., C.E.,

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Perhaps there is no more unsafe proceeding in science than to attempt to predict the limitation of the development of any of its results. Yet the theory of the steam engine has so far been developed as to seem to permit us to mark out the boundaries of its progress with tolerable accuracy.

At least, we trust that a full criticism of its present deficiencies, and a deduction of its limitations from known laws, will interest such of our readers as are engaged in the improvement of this machine, to which our civilization is more indebted for its advancement than to any other one thing.

In this article we will consider the steam engine alone, as it is in no wise responsible for the economy of the boiler which supplies the steam, or for the losses incurred in conveying the steam from the boiler to the engine.

The boiler should be considered apart from the engine, and it is well to incidentally remark here that the performances of the best types of boiler leave but little room for improvement so far as evaporation is concerned.

It is rather in the utilization of the steam after it reaches the engine that we must look for progress, and in this point, we take it, lies the value of a thorough investigation of the machine itself.

The well-known formula for the horse-power of a steam engine* contains three factors, which can be varied at will: the mean effective pressure, the volume of the cylinder, and the number of strokes per minute.

Concentration of power in a small space is the greatest attribute of the steam engine; it is its power to concentrate the strength of thousands of horses in the space of an ordinary room that renders the steam engine so useful and indispensable to us.

For this reason we cannot go on increasing the volume of the steam cylinder indefinitely without a proportionate increase in power, and it is only necessary to remark to mathematicians, with regard to the proportions of the cylinder, that that cylinder whose stroke equals its diameter contains the maximum of volume with the minimum of condensation surface.

The importance of reducing condensation surface is becoming more and more appreciated among engineers, and shortening the stroke will prove less of a bugbear when the laws of inertia, as applied to the reciprocating parts of a steam engine, are better understood.

Shortening the stroke has the further advantages of shortening the space passed over by the piston head during a given number of strokes, and consequently of reducing the wear on the piston head, as well as of rendering the engine more compact for a given power.

The following formula gives for any assumed horse-power, mean effective pressure, and number of strokes per minute, the required common diameter and stroke of cylinder, *in inches:*

$$d = 79{\cdot}59 \sqrt[3]{\frac{(HP)}{N\,P}} \dagger$$

Concentration being attained, the next important consideration that arises is *economy of steam,* and this is the battle ground upon which the struggle for supremacy among our engine builders is to-day

* $\frac{P\,L\,A\,N}{33000} = (HP)$. In which P = mean effective pressure per square inch, L = length of stroke in feet, A = area of piston in square inches, N = number of strokes per minute, (HP) = indicated horse-powers, $\frac{AL}{144} = V$ = volume of cylinder.

† *The Relative Proportions of the Steam Engine,* p. 16. Marks.

being practically fought out, while the physicists are quite as lively engaged in a dispute as to the relative theoretical merits of steam, hot air, and electric engines, into which we will not enter.

Practically, we think that, as far as the steam engine is concerned, the impossibility of supplying to the steam in the cylinder any appreciable amount of heat by means of steam or hot air jackets is acknowledged by all, and the jacket is only expected to keep the cylinder warm, and prevent it from abstracting heat from the steam inside the cylinder.

The jacket proving imperfect, we must find other means for preventing condensation by cooling, and they are these: Diminution of condensation surface, as already stated above, and shortening of the duration of the time for condensation, which means an increase in the number of strokes of the piston. The effect upon the structure of the engine of increased rotative speed is not injurious to the engine, as so positively stated by many engineers; but, if attempted, rapid speed requires a far greater knowledge of the dynamics of the steam engine than has as yet been applied to it by many constructors, and will almost inevitably shake to pieces a faultily designed structure.

The length of the crank pin and shaft bearings must also increase directly with the number of revolutions made, while their diameter, within ordinary limits as to pressure and speed, has no appreciable effect upon the heating of the bearing; but when we consider the practical fact, that the eccentrics, possibly because of greater speed of rubbing surfaces, are always sources of large frictional losses, it would seem best to make the diameters of all bearing journals just as small as the pressures allowable upon the surfaces of contact will permit. Much yet remains to be determined with regard to the laws controlling bearings. A very interesting work has been published on *Friction and Lubrication*, by Professor Thurston, but it is to be regretted that he has formulated the results of his experiments with so much positiveness, as other and careful experimenters have found it difficult to obtain results which clearly verify each other.

He has shown conclusively that the coefficient of friction is much affected and reduced by the state of the rubbing surfaces, by the method of lubrication, and by the quality of the lubricant.

Perfect, almost mirror-like, surfaces reduce the coefficient of friction far below the 3 to 5 per cent. formerly stated by Morin as a minimum, provided a continuous lubricating apparatus is used with good

sperm oil, and it will be found that a costly lubricant such as sperm oil is cheapest where care is exercised not to waste in its application.*

The important influence of the number of turns upon the length of bearings has not been clearly enough understood to prevent accidents from heating of the crank pins and bearings, which is one of the most annoying mishaps which can befall an engine, and at times requires the utmost vigilance of the engineer for its prevention.

The great difficulty attendant upon making bearing and shaft press uniformly throughout the length of the journal has almost forced the use of Babbitt or soft metal for high speed engines, and where proper care is taken in proportioning the results have justified its use.

Crank pins shrunk in by heating the crank, are apt to be out of truth, no matter how carefully the work has been done, as heat is apt to warp the crank.

Pins should be forced in cold, or the crank and pin be forged in one piece as in the case of most small double cranks.

High rotative speed, while increasing the power of the steam engine, also renders it more compact and diminishes the weight of the fly-wheel necessary to obtain regularity of speed.

Rotative speed has, however, its limitations, independently of the trouble sometimes caused by the heating of bearings.

For instance, it can be shown that if the safe stress in tension upon cast iron equals 1800 pounds per square inch, that a cast iron ring can be revolved safely at a maximum lineal speed of 8000 feet per minute, or thereabouts, which at once places a limitation upon the rotative speed of the fly-wheel, and demands reduction of its diameter as the rotative speed is increased.

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* Let l = the length of the crank pin, in inches.
" L = " stroke, in feet.
" (IHP) = the indicated horse-power.

Then, for marine propellor engines, a practical formula, giving safe lengths, would be

$$l = 0622 \frac{(IHP)}{L}$$

One-fourth of this length will serve safely for side-wheel or stationary engines.

For locomotive engines practice seems to prove that $l = 013\ d^2$ is a safe value, in which d = diameter of the steam cylinder, in inches.

For crank shaft bearings, letting R = the whole maximum weight on bearings, and N = the number of strokes per minute, we have $l = 000005\ R\ N$.

Let N = the number of revolutions per minute.
" D = the diameter of cast iron ring, in feet.
We have

$$\pi D N = 8000$$

or

$$D N = 2546.$$

This formula would limit the diameter of the fly-wheel of a pair of engines, to make 600 revolutions per minute, lately proposed by the distinguished engineer, Mr. Chas. T. Porter, to about 4 feet.

Of course, as the tensile strength of the material of which the fly-wheel is made is increased, the lineal speed at which it can be driven is increased.

If we take 5000 pounds per square inch as the safe tensile strength of the steel tire of a locomotive, we find its lineal speed to be limited to about $2\frac{1}{2}$ miles per minute, or 150 miles per hour, and it only remains for our engineers to provide boiler capacity and road bed adapted to such speeds, in order that they may be realized by a properly constructed locomotive.

This speed would shorten the time between New York and Philadelphia to 36 minutes.

High rotative speed necessitates special precautions as to the weight of the reciprocating parts.

If we impose the condition that the initial and final stresses upon the crank pin be equal, we must make the centrifugal force of the reciprocating parts (piston, piston rod, cross head and connecting rod), supposed to be concentrated at the crank pin, equal to half the difference of the initial and final steam pressures upon the whole piston head.

High rotative speed has also demanded a change in the form of the connecting rod, which was formerly largest at its mid-length, but has of late years been made largest at the crank pin end; a consideration of the stress upon it, due to its own inertia, would place the point of greatest stress at 0·578 of its length from the cross head end, but the stresses due to the twisting of the crank pin in its boxes recommends as a measure of safety that the rod be made largest at the crank pin neck, and tapered down from that to the cross head.

In a properly proportioned engine, of any assumed horse-power, the *only* method of reducing the weight of the moving parts is to increase the rotative velocity; lengthening the stroke will not do it.

The points of interest with regard to the volume of the steam cylin-

der and the rotative speed of the engine having been touched upon, there remains to be considered the mean effective pressure of the steam.

In the JOURNAL OF THE FRANKLIN INSTITUTE for June, 1880, the writer has shown, under the assumption that the steam expansion curve is an equilateral hyperbola, that the most economical point of cut-off for steam engines is determined by dividing the absolute back pressure by the absolute initial pressure of the steam.

Indicators do not give such curves, even if in perfect order, unless the steam is a little wet; but the approximation is sufficiently close for all practical purposes.

A more accurate way would be to say that the most economical point of cut-off is attained when the final steam pressure equals the back pressure; but our first statement is more convenient in form and will serve our purpose, with all the practical accuracy necessary.

Let P = the mean effective pressure of steam in pounds per square inch.

Let P_b = the initial absolute pressure of steam in pounds per square inch.

Let B = the back absolute pressure on piston in pounds per square inch.

Let c = the fractional part of the stroke at which the steam is cut off.

Let V = the volume of the steam cylinder in cubic feet.

Then we have

$$P = c\,P_b\left[1 + \text{nat. log. } \frac{1}{c}\right] - B$$

Let (HP) = the indicated horse-power.

" S = the specific volume of the steam for a pressure, P_b.

" W = the weight of water used per horse-power.

We have

$$(HP) = \frac{P\,L\,A\,N}{33000}$$

in which L = the length of stroke in feet.

N = the number of strokes per minute.

A = the area of the piston head in square inches.

Therefore

$$(IHP) = \frac{\left(\frac{1}{\epsilon} P_1 \left[1 + \text{nat. log. } \frac{1}{\epsilon}\right] - B\right) V N}{33000} \times 144$$

since $144\ V = L\ A$.

The quantity of water used during one minute is

$$62\tfrac{1}{2}\ \frac{\epsilon\ V\ N}{s}$$

$62\frac{1}{2}$ pounds being taken as the weight of one cubic foot of water.

Therefore, the weight of water used per horse-power is

$$W = \frac{62\frac{1}{2}\ \frac{\epsilon\ V\ N}{s}}{\frac{144}{33000}\left(\frac{1}{\epsilon} P_1 \left[1 + \text{nat. log. } \frac{1}{\epsilon}\right] - B\right) V N} =$$

$$\frac{14323\ \epsilon}{s\left(\frac{1}{\epsilon} P_1 \left[1 + \text{nat. log. } \frac{1}{\epsilon}\right] - B\right)}$$

If in this last formula we substitute $\frac{B}{P_1}$ for ϵ we obtain the theoretical minimum quantity of water to be evaporated per horse-power, and

$$W = \frac{14323}{P_1 s \text{ nat. log. } \frac{P_1}{B}} = \frac{62203}{P_1 s \log. \frac{P_1}{B}}$$

For one horse-power per hour we would have, multiplying by 60,

$$60\ W = \frac{373218}{P_1 s \log. \frac{P_1}{B}}$$

As, for instance, for a non-condensing engine having a gauge pressure of 45 pounds, and cutting off at $\frac{1}{4}$ the stroke, we find the minimum limit of evaporation of water required to be about 24 pounds of water per horse-power per hour.

Mr. Charles E. Emery has experimentally realized as low as 30 pounds of water per horse-power per hour with the given pressure, in small non-condensing engines.

If, in the last formula, we regard the product of the pressure, and the specific volume, $P_1 s$, as constant, which it is with a considerable

degree of approximation, we observe that the economy varies directly as the log. $\frac{P_b}{B}$, showing that both Watt and Oliver Evans were partially right in their attempts to increase the economy of the steam engine. Watt was right in perfecting more and more the vacuum obtained, and Evans in increasing the steam pressure at the boiler. Neither of them were wholly astray, but were soon met and their progress stopped by the slow increase of the economy beyond certain limits, and by the practical difficulties arising in the pursuit of a partially apprehended law.

It is evident that we are limited as to the steam pressure, and that a great increase of that, or a great decrease of back pressure, by reason of more perfect vacuums, will render the point of cut-off so early, and the mean effective pressure so low, that the necessary increase of volume in the steam cylinder will prevent that compactness and concentration of power so desirable in the steam engine; and, although it has already been shown that high rotative speed aids in rendering the engine compact, we are also limited in that direction.

Regularity of speed is an imperative condition in all engines used to drive high-speeded machinery; under such circumstances, regularity becomes the first requisite, and to it all other considerations must be subordinated.

Mr. G. H. Corliss, with his automatic cut-off engine, was the first to satisfactorily solve this problem.

With a constant steam pressure and a constant load, an engine will run, under the control of a throttling governor, with an approximation to regularity determined by the sensitiveness of the governor. With a throttling governor every change of the steam pressure, every change in the load causes a change in the speed of the engine, no matter how well proportioned it may be.

The laws regulating the centrifugal governor are such as to prevent it from ever becoming a very perfect mechanism, for the engine *and governor* must go fast in order to go slow, and *vice versa*. With an automatic cut-off governor, the speed will be held with regularity under all steam pressures and loads within its capacity, the approximation to perfection attained being determined by the proportions of the flywheel and the sensitiveness of the governor.

Governors in which the inertia of the balls is utilized to check any attempted change of speed, without an appreciable change of speed in

the governor itself, will ultimately supersede the centrifugal governor, which is full of radical defects.

Valve motions, actuated by a weight or spring released automatically by the governor, are comparatively so slow in their motions as to prevent high rotative speeds and short strokes. This form of valve motion has been elaborated with great skill and ingenuity on such engines as the Corliss, Harris-Corliss, Reynolds-Corliss, Wheelock's and Brown, which, so long as long stroke and slow rotation is adhered to, leave but little to be desired on the score of regularity of motion or perfection of workmanship.

To a different class belong the Porter-Allen and the Buckeye engines; in these engines, which are the exponents of high rotative speeds and short strokes, the cut-off of the engine is actuated by means of a link or an eccentric, whose position is regulated by means of a centrifugal governor, and, whatever the speed, the valves must keep pace with the engine in its motions.

A large number of valve motions are in use on the various forms of locomotive, marine and stationary engines, throughout the civilized world, and it is perhaps worth our while to practically note the important points of some of the older forms.

The plain hollowed slide valve is the most commonly used on the rougher forms of engines, because of its simplicity; as, however, the earliest point at which it can cut off steam without choking the exhaust is about $\frac{3}{4}$ of the stroke, it is not economical with the high pressures of the present day or with the vacuums ordinarily attained in condensing engines.

When a reversing gear is used, the Stephenson link motion is commonly used, where simplicity of mechanism rather than economy of steam is a point to be gained.

With open rods it has a variable lead, decreasing from the dead point; with crossed rods it has a variable lead, increasing from the dead point.

For crossed rods, the position of the piston is nearly constant at the opening of the steam ports; this is a decided advantage. Crossed rods permit a slightly greater length of eccentric rods.

Fastening the link to the ends of the eccentric rods, at a point behind the centre line of the link, as is usually done in American practice, introduces irregularities into the point of cut-off, but does not affect the lead.

When the ends of the eccentric rods are fastened to the link, at points on the centre line of the link, this error does not occur, but larger eccentrics are required, which are sometimes inconvenient.

The mode of suspension of the link is far more important than is usually supposed, as imperfect suspension not only introduces serious errors in the valve motion, but also affects the durability of the construction, by producing excessive slip in the block.

Where a constant lead is desired, using different angles of advance for the two eccentrics will produce a constant lead in one direction of motion, but ruins the action of the valve motion in the opposite direction.

The Gooch link motion is difficult to fit into an engine, because of the distance required between the centre of the crank shaft and the end of the radius rod; it is very easy to handle, and should therefore be used where frequent reversing is necessary, as in the cases of yard locomotives and hoisting engines, even though requiring considerable trouble to fit in.

If a constant lead be a great advantage, this link motion has this advantage. The suspension link for the link proper should be made as long as possible, and the suspension link for the radius rod should be attached as closely as possible to the link block. The tumbling shaft should be placed on the opposite side of the link from the crank shaft.

Allan's link motion, having a straight link, can be more easily fitted up than motions having a curved link; it has all the disadvantages of the Gooch link motion, but, unlike it, has not a constant lead, and has a greater number of parts. Particular attention must be paid to the relative lengths of the tumbling shaft arms for simultaneously raising and lowering the link and radius rod. The Allan link motion does not handle as easily as the Gooch.

Heusinger von Waldegg's link motion is the easiest of all to handle; it can be so arranged as to have very little slip in the block, but cannot be easily attached to all forms of crosshead.

It is the simplest reversing gear yet mentioned, and has a constant lead.

Pius Fink's link motion is the simplest reversing gear in existence which at the same time can be adjusted as a cut-off; it has a constant lead, but a limited range of action, and in this point is inferior to all

the others, as well as being irregular in its variation from its calculated positions.

However, if carefully designed it will do good work, and is very easy to handle and very durable.

The fact that it is impossible to avoid choking the exhaust, and the consequent compression of the steam, thereby reducing the power of the steam engine whenever the attempt is made to cut off early in the stroke with a single valve has led engineers to devise double valve motions which will effect an early cut off of the steam, independently of the motion of the hollow of the slide valve relatively to the exhaust.

To this type belong the valve motions of the Porter-Allen and Buckeye engines, both of which show a wide range of action for motion in one direction, and great simplicity of structure.

The Gonzenbach link motion, with its double steam chest and excessively complicated outside gear, is now almost obsolete; it will not cut off sharply and well, except for very early points, and that, too, only for motion in one direction, and when properly arranged for working in one direction gives a double admission of steam for motion in the opposite direction; it is difficult to handle, and its complication renders it very liable to break down.

The Polonceau link motion, while it has not the double steam chest or as much complication in its outside valve gear, cannot cut off steam later than ½ of the stroke, and is therefore not very well adapted to general locomotive use where economy is sacrificed to concentration of power.

It is not very difficult to handle, but, like the Gooch, presents some difficulty in adapting to the narrow limits offered by a locomotive.

Meyer's link motion seems to have met with the greatest favor from builders of marine and stationary engines, as it presents a wide range for motion in one direction, and a greater range when used as a reversing motion than any of the others.

The screws which move the expansion blocks are liable to rust or wear, and cause trouble; the expansion valve should have separate eccentrics to work best; it is intricate in its construction, and liable to break down.

It is also difficult to handle, and absorbs much power unless the distribution valve is balanced.

An ingenious modification of the Meyer valve motion is the Ryder

cut-off, in which a cylindrical expansion valve, whose edges approach each other after the manner of an isosceles triangle wrapped around a cylinder, is moved around its axis by means of the governor, so as to have the same effect as that of increasng or decreasing the distance between the expansion blocks of the Meyer cut-off.

In order that we may make ourselves clearly understood, we recapitulate.

A really good steam engine should possess the following qualities: Concentration of power, economy of steam, regularity of speed, simplicity of design and durability of construction.

We have endeavored to mark the limitations of the first three attributes of a good engine; the last two must be worked out in the shop.

We are, perhaps, too bold in our prediction, but it seems to us that the engine of the future will have a cylinder whose stroke is equal to its diameter, its speed will be limited by the tensile strength of its revolving parts, its bearings will be of great length, its cut-off will be determined, approximately at least, by the ratio of the back pressure to the initial pressure, its valve motion will be rigidly in connection with the crank shaft, its reciprocating parts will be so proportioned as to put a nearly constant pressure on the crank pin, its flywheel, if it has one, will be proportioned so as not to admit of more than a predetermined variation of speed during one stroke, its governor will no longer be centrifugal but a revolving pendulum, almost isochronous, and holding the engine, with all necessary approximation, within fixed limitations, to a constant speed.

Philadelphia, June 25th, 1880.

Influence of Winds on the Barometer.—When a balloon is borne along by a rapid current calculations of its altitude are not trustworthy. When the velocity is very great, the error may be as great as one-third of the estimated height. Kaemtz, from the study of barometric observations at Paris, Zurich, Berlin and Halle, found that the readings were affected by the direction of the wind. Montigny has discovered a similar influence at other stations, but at Brussels and Namur the influence is directly opposite to that at Antwerp. —*Les Mondes.* C.

ECONOMICAL CUT-OFF IN STEAM ENGINES.

By S. W. Robinson
Of Department of Mechanical Engineering, Ohio State University.

Theoretically the most economical cut-off is readily seen to be that by which the steam at the instant of release has, in the particular cylinder, and under the particular conditions, no capacity for developing further work.

In a cylinder of indefinite extent, having one fixed head and a moving piston between which steam has been admitted to a certain point, then cut off and expanded, the best point theoretically at which to release the steam will be where the pressure has fallen by expansion to the back pressure. This is evident from the fact that up to this point there is an effective pressure upon the piston to urge it forward, while beyond this point the effective pressure is backward, or prejudicial. An indicator card taken from an engine working under these conditions will have a sharp point at the end, or termination of stroke. If the atmosphere is the back pressure, as in case of non-condensing engines, then the release occurs where the expansion pressure equals one atmosphere. In condensing engines it is where the expansion pressure equals the pressure of the condenser, where the back pressure is zero, if possible, it is where the volume of expansion is infinite. For this latter case the above ideal cylinder must be of infinite length.

For all the above cases, the ratio of expansion is equal the pressure of admission divided by the back pressure, where Mariotte's law of expansion holds; since, by this law, initial pressure × initial volume = final pressure × final volume. Or,

$$\frac{\text{initial pressure}}{\text{final pressure}} = \frac{\text{final volume}}{\text{initial volume}} = \text{ratio of expansion.}$$

This result agrees with that obtained analytically by Professor Wm. D. Marks in the June number of this Journal, where the simple rule for finding the most economical point of cut-off, *stated in words as that by which the terminal pressure must equal the back pressure*, was looked for without success. According to this rule, the indicator card shows at a glance when the specified adjustment is realized.

This adjustment of the cut-off is pretty generally accepted by engineers as the best *theoretically.* But in actual steam engine practice the adjustment will be quite different, for several reasons, such as excessive size of cylinder, causing loss by radiation of heat and cooling by expansion, friction by mechanism, undue strains of parts or increased piston speed, etc. For instance, the size of the crank pin enters into the problem. In practice, the indicator diagram from an engine running under the most favorable conditions, or with the most economical practical cut-off, should show its narrow end cut square off with some considerable breadth, instead of being absolutely sharp; and what breadth it should have is a matter not easily determined. To illustrate, take an example of a non-condensing engine working under 90 pounds absolute pressure of admission per square inch, cutting off at one-fourth the stroke. The terminal pressure will be $7\frac{1}{2}$ pounds above the atmosphere, Mariotte's expansion; but if the cylinder were 50 per cent. longer, the terminal pressure would be just the atmospheric, or that required by the solution given by Professor Marks. The gain in work done per stroke, for the 50 per cent. longer cylinder, will however be, as found by calculation, less than 4 per cent. of the work done without the 50 per cent. added.

To save this 4 per cent., the engine, for a given establishment, would require to be one-half larger, making the same number of strokes per minute. Or, if the number of strokes diminish with increase of size, it would need to be more than a-half larger. Aside from the considerations of greater loss of heat by radiation, cooling of steam, friction, etc., there comes the interest to be paid on the additional investment required in the larger engine. In the light of considerations like the above, which must be familiar to professional as well as practical engineers, it would seem that the qualifications needed to the last sentence in Professor Marks' article must, through some hurry or otherwise, have been overlooked, but which, it is hoped, will be fully supplied in the article promised soon to follow.

French Railway Union.—The French railway companies have decided to establish a common tariff for all the districts of France. The plan which they propose to adopt will enable all freighters to calculate, before shipment, the charges upon packages of every description.—*Chron. Indust.* C.

PROGRESS OF THE DEPHOSPHORIZATION OF IRON (CONTINUED).

By F. Gautier.

Read before the Society of Civil Engineers of Paris, January 16, 1880.
Translated by CHAS. T. ROLLIN.

Experiments in Austria.—The works of Witkowitz, situated in Moravia on the prolongment of the coal basin of Silesia, found a difficult to procure ores of sufficient purity for treatment by the Bessemer process; their only stock was the carbonated iron of Eisenerz, at the extremity of Styria. Therefore, seeing great usefulness in the Thomas-Gilchrist process, these works were the first on the continent to put it in practise.

The bricks employed for the lining had the following composition:

Lime and magnesia,	96
Alumina and oxide of iron,	2
Silica,	2

The most interesting features connected with the experiments at Witkowitz, are the employment of two converters, one with an ordinary silicious lining, the other with a basic lining, and the changing of the metal from one to the other during the operation.

A ladle received from the blast furnace the metal which had the following composition:

Carbon,	3·6—4
Silicon,	2·5
Phosphorus,	0·17

This metal is very low in phosphorus and ought to give no trouble in the special treatment to which it was subjected. By having very little carbon and finishing with ferro-manganese they were able to make good rails from it.

The metal after treatment in the first or silicious converter, had the following composition:

Carbon,	0·22
Silicon,	0·81
Phosphorus,	0·20

This metal was cooled in a ladle, which was then lifted by means of a locomotive to the level of the basic converter, in which the refining was finished.

The steel obtained had the following composition:

Carbon,	0·14
Silicon,	traces.
Phosphorus,	0·036

They have not given sufficient details in regard to this operation; for instance, we do not know if there was any overblowing for such a small amount of phosphorus.

The loss was 18 per cent.; as to the product, it was of excellent quality, comparable to that obtained from the best charcoal iron of Austria.

Tests for tensile strength, with bar 100 millimetres in length, gave the following results:

Resistance,	45 kil.
Elongation, per cent.	29 "
Contraction, per cent.	62 "

But what seems to result from changing from one converter to another, at least so far as it has been tried, is that it prolongs the operation 15 minutes and causes a very marked cooling.

Dephosphorization on furnace bed (sur sole) is far from having attained such practical results as dephosphorization in the Bessemer converter.

The question of the production of dephosphorized steel on a furnace bed occupies the attention of many metallurgists; but since my communication of July last, there has appeared no further information with regard to experiments with the Ponsard furnace-converter in Belgium. It will be remembered that in experiments with this furnace, the heat was insufficient and did not permit the entire charge leaving the furnace. The value of the metal in rolling cannot therefore be definitely stated.

The following complete analyses, made in the laboratory at Creuzot, of samples of the metal and of the slag taken during the operation give us all the information we have:

Description.	Time of Taking Sample.	Carbon total	Carbon	Manganese	Phosphorus	Sulphur	Silicon	Aluminum	Protoxide of Iron	Lime	Magnesia	Phosphoric Acid	Sulphuric Acid	Protoxide of Manganese	Total
Rail Metal. Creuzot.	E.	1·917	0·454	0·324	1·041	0·322									
1st Sample.	2hours.	1·754	0·154	0·189	1·556	0·056	33·525	7·370	9·102	10·850	8·784	1·256	1·767	17·184	98·308
2d Sample.	3h. 02.	1·572	traces.	0·170	1·380	0·059	21·335	5·994	10·959	35·700	7·903	3·556	0·812	11·950	99·79
Blowing.															
3d Sample.	3h. 51.	0·497		0·140	1·104	0·240	25·681	7·787	10·215	35·750	8·454	3·304	0·987	7·965	101·28
Cooling of the Slag: 50 kil. Lime, 197 kil.															
4th Sample.	4h. 45.	0·517		0·125	1·101	0·232	20·615	6·522	6·750	49·480	12·941	1·345	0·740	6·025	98·101
50 kil. Lime, 50 kil.															
5th Sample.	5h. 45.	0·150		0·075	0·580	0·245									
125 kil. Lime, 125 kil.															
6th Sample.	7 hours.	0·280		0·080	0·559	0·255	17·450	11·028	14·991	47·180	7·293	1·572	0·260	4·180	98·217
25 kil. Lime, 25 kil.															
7th Sample.	7h. 25.	0·180		0·075	0·135	0·227	14·785	8·45	27·168	32·250	6·445	0·502	0·472	2·171	99·72
Cooled: 50 kil. Ferro-Manganese, 70 per cent.															
8th Sample.	9h. 30.	0·405		0·235	0·033	0·267	12·345	11·258	21·987	32·850	6·917	2·342	1·079	11·190	99·891

It can easily be seen, that if the heat had been sufficient they would have been able, with iron containing about 2 per cent. of phosphorus, to have obtained steel containing less than a half-thousandth.

Dephosphorization by the Krupp process.—The Krupp or Narjes-Bender process does not pretend, under the most favorable conditions, to remove from the metal more than 80 per cent. of its phorphorus. This dephosphorization accompanies the almost complete disappearance of the silicon; the product resulting from it, although still containing all its carbon, cannot be used in the Bessemer process. On the other hand, with a highly phosphoric metal, such as that of Cleveland, of the Moselle, or of Luxembourg, which contains 1·5 to 2·0 per cent. of phosphorus, a purified metal is obtained, having still at least 0·3 to 0·5 per cent. of this impurity, which is rather much for employment in the Martins-Siemens furnace. It is necessary to drown this phosphoric material in a mixture of scrap of the first quality, which is another difficulty. The veritable employment of the Krupp process, outside of particular cases, is then the production of non-silicous and notably dephosphorized metal by an operation which seems quite economical; we ought to be grateful for this much. The same pig-iron, easy and advantageous to puddle, would permit the production of improved iron; employed directly in the foundry it would give castings of very much greater resistance. It seems to us, that it is necessary to consider the Krupp process in the above general manner. The results of this process, without doubt very interesting, cannot compete with the Thomas-Gilchrist process, for the production of steel from very phosphoric pig-iron.

In order to complete the data which I have already given, I will make some quotations from the study which Mr. Holley has published in regard to this process.

The furnace is a sort of Pernot furnace for the fusion of steel; that is to say, it is heated by the Siemen's system, and its bed is movable; it has an outside diameter of 4 metres with a "trough" 1 metre in depth. The lining, which has a thickness of 20 to 30 centimetres, is composed of blocks of iron ore, the interstices being filled up with small ore. The surface is glazed by a preliminary heating while the furnace is turned with a speed of only 3 or 4 revolutions per minute. Repairs are made in the same manner by means of a mortar of this same ore, which is applied to the corroded spots.

It is easy to obtain ore of the necessary composition. It must not

contain less than 6 per cent. of silica, in order that it will be able to agglomerate, and not more than 15 per cent. to prevent melting. As to other elements they are not questioned; we thus have dephosphorization with ores having 4 per cent. of phosphoric acid. This is a fact which Mr. Bell had already brought to light in dephosphorizing Cleveland iron with phosphoric ores.

We give below several examples of treatment:

Phœnix Iron.

Description.	Before.	After 4 min.	After 5.30	After 7
Carbon,	3·	3·27	3·27	3·32
Silicon,	0·39	0·02	0·01	0·083
Phosphorus,	0·74	0·16	0·146	0·106
Sulphur,	0·09	0·024	0·026	0.029
Manganese,	2·32	0·038	0·116	0·058

Slag.

Silica,	13·0
Oxide of iron,	51.0
Oxide of Manganese,	16·6
Alumina,	11·6
Lime,	0·7
Phosphoric acid	6·0
Sulphuric acid,	0·2

Heede Iron.

Description.	Before.	After Treatment.
Carbon,	2·50	2·40
Silicon,	0·20 to 0·30	traces.
Phosphorus,	2·60	0·65 and 0·90
Manganese,	2·60	traces.

Description.	Ore of Heede	Slag Produced
Silica,	4·80	10·40
Oxide of Iron,	52·60	41·00
Oxide of Manganese,	8·36	19·30
Alumina,	1·20	2·00
Lime,	11·73	7·30
Magnesia,	0·80	0·70
Phosphoric Acid,	3·83	20·00
Carbonic Acid,	7·90	——
Water,	7·88	——

Luxembourg Iron.

Description.	Before.	After Treatment.
Carbon,	3·40 to 3·10	3·30
Silicon,	0·46 " 0·59	traces.
Phosphorus,	2·23 " 2·09	0·65 to 0.95
Manganese,	0·18 " 0·19	traces.

Description.	Luxembourg Ore.	Slag.
Silica,	7·6	9·5
Oxide of Iron,	65·0	70·3
Oxide of Manganese,	0·2	2·1
Alumina,	3·0	4·1
Lime,	10·2	1·9
Magnesia,	2·7	0·3
Phosphoric Acid,	2·2	11·5
Sulphur,	0·1	0·3
Water,	9·0	——

The iron treated ought not to contain more than 1 per cent. of silicon; otherwise the furnace bed would be very much corroded. The less there is of silicon the better the operation proceeds; they sometimes change the composition of the linings by adding a little lime in proportion to the amount of silicon in the pig-metal. Manganese is recommended as facilitating the operation; they add this in the form of spiegel when there is none of it in the pig-metal. Manganese protects the carbon from oxidation, maintains fluidity and produces very good effects.

The charge is from 5 to 7 tons of metal. As soon as it is introduced the rapidity of turning the furnace is increased to 11 revolutions per minute. After two or three minutes boiling, accompanied by disengagement of carbonic oxide, commences. Altogether, the operation is very short, ten minutes at most; as much more time is necessary for stopping the furnace, cooling, etc. One hour and a half is sufficient for the dephosphorization of 5 to 7 tons of metal, repairing and reheating a new lining. Thus 12 hours permits 9 operations, or 80 to 90 tons of dephosphorized metal in 24 hours. The loss is small, and varies from 2·5 to 10·0 per cent. at the most, because there is a slight reduction of the ore used in lining: the operation is, therefore, not very expensive. Mr. Holley published the following information, which is rather insufficient:

1025 kilogrammes of metal, at 58 francs,	60.00 f.
Fusion in the cupola,	4.25 f.
Dephosphorization, lining, coal and labor,	6.25 f.
	70.50 f.

Mr. Peterson, engineer at Eschweiler, gives the following:

Consumption of ore from 18 to 30 per cent., proportional to the amount of phosphorus, without taking into account 6 per cent. of rich oxide of iron in the initial lining, but which is not renewed until the bed of the furnace is completely rebuilt:

Coal,	9 per cent.
Labor,	1.10 f. (about).
Repairs,	0.45 f.

Even taking into account the low price of labor and raw materials in Westphalia, the Krupp process must be considered as not at all costly in any part.

Laws regulating the Spheroidal State of Matter.—P. H. Boutigny states that the temperature of bodies in the spheroidal condition is always below that of ebullition; for water it is 97° (206·6 F.). The spheroidal matter is never in thermal equilibrium with the vessel which contains it, but the vapor which escapes from it is always of the same temperature as the vessel. The spheroidal matter reflects radiant heat. The volumes of matter in a spheroidal condition are in a ratio inverse to their densities, and their masses are uniform. Some of the phenomena seem to indicate a repulsive force acting at sensible distances before vapor can be disengaged.—*Comptes Rendus.* C.

Variations of Temperature at Different Altitudes.—During periods of severe cold in 1879 and 1880 observations at various stations by Alluard, Faye and Lemoine showed that in the basin of the Seine, in the environs of the Puy de Dome, and in various parts of Burgundy, the cold was less intense at elevated stations than at ordinary altitudes. This difference was shown not only in the coldest but also in the warmest parts of the day. At La Croisette, near the summit of the Morvan, one of the most elevated stations, the sky was entirely clear from the 18th to the 28th of December, both by day and by night, while upon the plain there was continual mist and frost.—*Comptes Rendus.* C.

THE RUSSIAN IMPERIAL YACHT "LIVADIA."

The Fairfield Yacht for the Czar, and Vessels of her Type considered as a means of International Communication.*

By E. E. Goulaeff, Captain of the Corps of Naval Architects, Russian Imperial Navy, Ad.C., F.R.S.N.A., M.I.N.A.

Gentlemen: In a few days you will see one of the most remarkable pieces of naval architecture glide gently into the waters of the Clyde. Already hundreds of people have visited the Fairfield Yard, coming nearly from all parts of the globe to see this wonderful ship, intended to serve as the sea-going yacht for the Emperor of Russia, and the interest in her seems to be growing with the growth of the ship.

So novel is this vessel, both in her principal features and in all her details, that her construction shows a wonderful combination of ideas and foresight, proving the extraordinary amount of inventive genius in the mind of her designer.

Being asked by your chairman to read a paper at this Institution, I could not refuse this offer, as I considered it a great pleasure and honor to be able to speak before the Fairfield Association of the "Fairfield child." But, in doing so, I must apologize at starting for my bad English, trusting you will excuse me, as my poor knowledge of your language comes only through my not being a Scotchman.

It seemed to me more suitable, on this occasion, to describe to you the ship herself in as few words as possible, giving only her principal features, and the main objects which were in view in designing her, and to dwell largely upon the probable development of this class of ships, when adapted for great peaceful and beneficial purposes.

The general appearance of the vessel can be judged from the photographs of the model, and from another picture, lying on the table, representing the yacht, when completed, steaming in the smooth sea.

This vessel is 235 feet long, 153 feet broad, and has a draught of 6 feet 6 inches. She might have been a little longer, but on closer investigation it was found that the addition of some 25 feet or 50 feet

* Paper read before the Fairfield Association of Engineers and Shipbuilders.

to her length would not have reduced the resistance in water. Augmentation of skin friction, not being sufficiently compensated by the improved lines, would have required increased power to drive the larger vessel with the given speed. She might have been a little narrower to suit the taste of most people, yet the beam of 153 feet cannot be regarded as being too great if we bear in mind the main object of her design, namely, the desire to secure the greatest steadiness.

Her small draught is perhaps the most peculiar of her features. Experimental analyses, agreeing with actual results derived from the trial trips of extremely broad vessels existing in the Black Sea, prove that at certain speeds a very much broader vessel requires only half as much power compared with another vessel of similar form whose draught is double. This is represented on one of the diagrams. The upper curve shows the resistance of the circular vessel, 120 feet long, 120 feet broad, and drawing 13 feet of the same displacement as the yacht, whilst the lower curve represents the resistance of the yacht drawing 6 feet 6 inches. Hence the importance for the vessels of that class to have the smallest possible draught, and hence the anticipation that great speeds are not incompatible with this form. The late Mr. W. Froude, who conducted, at the request of Admiral Popoff, some experiments with the models of vessels of his design, was the first to demonstrate by exact data the influence of draught on the reduction of resistance. No doubt, such reduction of the total resistance, with the reduction of draught and the increase of other dimensions, is owing to a great diminution of the wave making; indeed, the diagram proves that the advantage of the shallow ship increases with the increase of speed, and, as you all know, at great speeds, according to Froude, the most important portion of the total resistance is the wave making. Such considerations and reasonings, agreeing, as I have stated, with actual trials of the existing vessels—one broader and shallower than another—determined the small draught which has been given to the yacht.

Thus we see that, under the circumstances, the principal proportions of the yacht could scarcely be altered in any way to the advantage of the ship.

Having specified the extreme dimensions, I will draw your attention now to the form of this vessel.

The form of underwater portion was made a subject of very care-

ful study. Besides the great experience of the designer of the ship, Admiral Popoff—experience which he derived by spending the greater portion of his lifetime, either on the ocean, or in constructing novel ships, and trying them at sea—Dr. Tideman, member of the Academy of Amsterdam, was invited to assist in the determination of questions connected with the resistance of the yacht.

In the case of this shallow draughted vessel, the fine lines must be the vertical sections, whereas the fine lines of the ordinary steamer are the water lines or horizontal sections. Such change has been brought about by passing from long, narrow and deep forms of ordinary vessels to the proportions of short, broad and shallow ones; and, as has been demonstrated by experiments with paraffin models, the sharpening of buttock lines is more essential in this case than sharpening of water lines. In other words, if the motion of an ordinary vessel may be compared with that of a wedge propelled vertically, the motion of the yacht ought to be compared with the same wedge propelled through the water horizontally. On looking at the stern of the actual vessel you will observe that the whole motion of the water between the stern tubes will be affected solely in the direction of the vertical sections, or the buttock lines. The diagrams give the principal sections and plans of the yacht. You will see that a large superstructure has been built upon the main body of the turbot-shape of the dimensions and of the form I have just mentioned. This superstructure is of the shape of an ordinary vessel, and because being of usual form, will no doubt gratify the eye of those who are not sufficiently educated to admire the uncovered sides of the lower turbot portion of the ship, which, however, are the very parts that have the greatest share in limiting the rolling at sea. Waves, from whatever point of the compass, developed either by the motion of the ship at very high speed, or by the capricious will of nature, will ascend up the rounded sloping sides of the vessel, but finding there perfect freedom for their play, will have soon to subside, as the sloping deck is of a shape that does not amit of green seas remaining long upon it, unless in the form of a very thin sheet of water, quickly disappearing altogether. No additional buoyancy, therefore, is created alternatively at either side of the ship, and hence the rolling becomes a motion which, in the big waves, might follow the steepness of the swell, and, in small waves, actually reduces itself to nothing. Very often when on board a circular ironclad steaming in a gale, watching the behavior of the boister-

ous seas about the rounded deck of the vessel, I was lost in admiration of the fruitless attempts made by the picturesque phosphorescent waves —illuminated brightly, on a dark night, from underneath by the deck lights—to produce any influence on the majestic steadiness of the ship. At that time, my deficiency in painting prevented me from the reproduction on canvass of my impressions. Here, before you, gentlemen, feeling my deficiency in English, I am again prevented from giving to you a better description of the phenomenon; but to complete what I said regarding the behavior of the seas about these vessels in heavy weather, I believe I cannot do better than to refer some of you, desirous of fuller information on that point, to the splendid articles which appeared in the *Times* newspaper from the pen of the eminent writer Mr. Reed, late Chief Constructor of the Navy, who described several passages made by himself on board of these typical vessels, and whose system of widening and shortening ships had much to do with the origin of the idea of circular vessels in the mind of Admiral Popoff. The parts beyond the superstructure already referred to, represent to you the extent of the palace carried by the yacht.

The turbot-like lower part of the vessel contains machinery, coals, and stores of all kinds. The steel superstructure rising over it contains accommodation for the crew forward, and for the officers aft, whilst the palace beyond it includes only the imperial apartments and the cabins for the suite.

This turbot-like portion of the vessel is built of steel, with a double bottom, whose height is no less than 3 feet 6 inches in the centre. This double bottom is divided into forty water-tight compartments, and extends throughout the flat portion of the bottom. At the sides it is superseded by the cells formed by running two vertical bulkheads right round the ship, and subdividing the distance between them and the outside skin into forty other compartments. These side cells, formed of continuous bulkheads, and covered by the plating of the rounded deck, present a very rigid, continous, annular structure, which has its lower points tied together by the radial girders, forming the bracket framing of the bottom, and by the heavy beams of the rounded deck, also radial, at the top. Thus the turbot-like portion of the vessel is made amply strong enough to withstand those forces which might be experienced in the roughest seas, and the local strains, such as those produced by the powerful machinery with which the ship is provided—particular attention being paid to the structure of the stern,

in order to distribute the strains on the brackets supporting the propelling shafts of the side screws.

I need not go into the strength of the superstructure that rises above the turbot portion of the vessel, as it has been mainly designed to form a support for the palace and deck-houses beyond, in order to raise them so much above the level of the sea as to prevent anything but spray reaching those portions which are intended for the use of the imperial party.

The palace, as will be seen from the diagrams, is not so wide as the steel superstructure, so that all around it on the deck a continuous gallery is formed, which is used for stowing anchors, mooring the vessel, hoisting up boats, steam launches, and a small steam yacht, carried an the davits, which are supported by bridges projecting radially outwards from that gallery.

The roof of the palace is carried right over to the same width as the lower superstructure, thus forming an awning over the gallery shading from sun or rain the lower story of the palace, and widening at the same time the promenade above. Inside the lower story forward, and away from the heat and smell of the engines and galleys, are the apartments for the emperor, and aft, those for the suite. Their number is not great, but their size is very much larger when compared with the cabins existing on board of any other ship. Accommodations of exceptional comfort had to be studied in this case. In the inside of the superstructure below here in the palace, the middle portion between the engine and boiler hatches is allotted to a passage across the vessel communicating with either end by means of two longitudinal passages, and also with the deck above. Such principal thoroughfare, by its convenience, marble pavements, electric lighting, etc., reminds one of the lofty staircases and spacious corridors in some palaces on land.

Beyond the promenade on the awning deck rises a reception saloon, whose height is 12 feet, and therefore greater than has been reached on board any other ship. In its forward part will play a fountain, surrounded by a bed of flowers. The whole decorative works of this saloon will remind us of the rooms of Louis XVI, at Fontainebleau, and the designs of this and other apartments were prepared by the well-known Scotch artist, Mr. W. Leiper. The drawing-room will be furnished in the Crimean-Tartar style, whilst other rooms will be of a

simple kind of modern English, regard being made to obtain the greatest comfort.

Behind the funnels on the same awning deck stands another deck-house, including rooms for the Grand Duke Constantine and the captain of the ship. Just in front of the funnels is the bridge, from which the ship will be governed, either by the steam steering gear acting upon her rudder, or by means of another gear designed for steering the vessel by means of her side screws.

It is scarcely possible to enumerate the improvements introduced in all their details. The system of distinguishing red, white and green electric lights has been worked out under the guidance of His Imperial Highness the Grand Duke Constantine. The system of pumping out the water-tight compartments is deserving of special notice, as does also the town-like system of water-service, to which, I believe, for the first time on board ship, there are added loaded accumulators to produce pressure when the steam pumps are not at work. Machinery has been employed largely to supersede manual labor, and there are no fewer than twenty-three separate steam engines on board for different purposes.

The propelling engines of the yacht, which have been designed by Mr. A. D. Bryce, are of a construction decidedly novel, and have been erected in a somewhat novel manner. Their foundation, which is of steel, forms part of the framing of the double-bottom, as is also the case, on a smaller scale, in the circular vessels. We hope that, with many other important improvements introduced in these engines, we shall obtain a greater amount of indicated horse-power, as compared with their weight, than with any other marine engine yet constructed (torpedo boats excepted), and that they will satisfactorily answer the problem entrusted by Admiral Popoff to Mr. Bryce.

The arrangement of propellers forms another very important peculiarity in the design of this vessel.

The efficiency of submerged screws beneath the ship's bottom has been sufficiently tested previously by Admiral Popoff, but so much as having two-thirds of their diameter entirely below the outline of the vessel is a decided novelty, which, as was expected, will greatly add to their efficiency, as has been corroborated by the recent experiments conducted to that effect, on Loch Lomond, with a steel model of the yacht one-tenth the ship's size. There are three screw propellers of 16 feet in diameter, spaced 18 feet 3 inches apart—the centre one being

in the line of keel, and each of them worked by an independent engine capable of exerting an indicated horse-power of 3500.

Now, having described to you the vessel, I shall beg you to turn your attention to the second portion of the paper, namely, to "vessels of her type considered as means of international communication."

During the last few years the means for such communication have reached a high state of development, and the great improvements introduced are already increasing and facilitating commercial, scientific, and friendly intercourse among the nations, and are tending to bring more and more the light of civilization to bear upon those portions of the human race whose isolation from other parts of the world was the only cause of their primitive state.

Already one immense line of railways crossing the continent of Europe, or that of United States of America, from end to end, competes with another line of similar extent, in affording comfort to passengers and in saving so many hours in the journey. Every year the number of railway companies continuing to disregard the comfort of travelers is decreased, and with the sleeping and dining cars introduced on nearly all lines of importance, traveling is done with such ease that the journey becomes no longer a source of trouble but the reverse.

However important in relation to the economical development of separate states are the means of communication just spoken of, there are others which are scarcely of lesser importance, especially so in relation to commerce and civilization—and one of these is the steam navigation. I specified it the steam navigation, because only the application of steam insured the possibility of establishing an uninterrupted connection of all parts of the world. So great is the demand for the means of emigration from the Old World to the New, often in very large masses of people, and the demand for the means of traveling, that already, at least one steamer a day is despatched from the shores of Europe to America, and, no doubt, the same will be the case with our communications with the other parts of the world, such as Australia, as soon as greater knowledge has been obtained of the climate and natural wealth of this new continent. Thanks to the continuous success in ship building—success for which we are greatly indebted to the Clyde shipbuilders—already the distance to America has been decreased to a week's journey, and to Australia, to a passage of one month. I know that Mr. Pearce is not satisfied with these results, though they were brought about partly through his own enterprise,

and is prepared to surpass them, being ready to construct a fleet of steamers that will run the distance from Liverpool to New York in less than six days, and will establish the "Express" Ocean Service.

Thus we see that the great strides in steam navigation have given us nearly as good means of rapid locomotion at sea as have been reached by railways on land, but so much cannot be said in relation to comfort. Notwithstanding an ardent desire on the part of shipowners to turn their steamers into floating hotels, as convenient for living and as luxurious in their internal arrangements as are hotels on shore, people, with very few exceptions, regard a voyage by sea with mistrust, and even with dread, at the thought of that helplessness to which are subjected both men and women, when the calm of the sea, so pleasant to travelers, changes into a heavy boisterous swell whose end no one can predict. No care in improving the internal accommodation, however luxurious—and, in most cases, more luxurious than the interior of the first-class railway carriage, at whatever expense to the owner of the ship the luxury is obtained—can alleviate these feelings of the masses of passengers. Fears of sea-sickness limit at present the number of travelers by sea actually to those who are obliged by necessity to go on board of a steamer of our day. Had the means existed to obviate, or at least to decrease, these inconveniences—nay, sufferings—I can predict that the numbers of those traveling on board the steamers would be increased to an enormous figure, which would result in the construction of new vessels of still greater speed, and with still better accommodation. The intercourse between nations would become much wider, and the beneficent results of enlightenment and Christianity would spread to the most distant countries. The islands forming Great Britain, remain comparatively speaking, in a certain sort of isolation in relation to the people's customs and habits, which make the Englishman abroad so different from any permanent resident on the Continent. The cause of this, according to the opinion of an eminent politician of the present day, can be traced in small and very inconvenient means of Channel communication. If a distance of twenty miles by sea can produce so marked a difference in the people, it seems to me that what I said before in reference to the improvement of the means of communication between one part of the world and another must present itself to our minds still more clearly, and prove that ameliorations in this respect are to be regarded as matters of great importance in the history of the world.

So far, the attempts in the direction of improving the Channel communication—attempts which were met by every one of us with sympathies and hopes, which brought forth the design of such original vessels as the *Bessemer* and *Calais-Douvres*—have failed, and thus the field for improvements in that line remains yet open.

I say that the problem of combining comfort with sea voyages is yet to be solved, not because we are wanting in the knowledge of the principles, the application of which would reduce suffering from seasickness to a minimum, but because, until the present time, there has been no opportunity for constructing a steamer on those principles specially intended for the combination of speed with extreme steadiness in a seaway.

The circular ironclads forming part of the Black Sea fleet were intended for purposes of coast defence, which confined them to a small speed of locomotion so as to be able to use the greater part of their displacement for the purpose of carrying their enormous guns and and armor, which they do actually carry upon their extremely small hull. Quite indirectly, after the completion of those vessels and at the time of their extensive trials at sea, their wonderful steadiness in the heaviest seas was demonstrated, owing to their beam, absence of freeboard and rounded-up deck. Thanks to the voyage of the High Admiral of the Russian Navy, the Grand Duke Constantine, across the Black Sea to Batoum and back along the Caucasian shore, exactly a year ago, many of the distinguished gentlemen who had the honor of attending His Imperial Highness on that occasion had the opportunity to witness for themselves the splendid behavior of these extremely broad vessels at sea, and they ceased to believe any longer in those curious articles in some newspapers which were sufficient only to prove how very little the writers were acquainted with naval architecture and seamanship. During that voyage, the steamer *Penderaclia*, of ordinary proportions, had the full angle of rolling (on both sides) 72 deg., whilst the full arc through which the circular vessel rolled did not exceed 6 deg., or 12 times less. The *Penderaclia's* oscillations per minute were 20 against only 9 oscillations in the same space of time of the circular vessel. These eloquent figures speak for themselves. They were obtained by careful observations made simultaneously on board of each of these two vessels, which were specially placed in exactly the same conditions in reference to the waves and the wind.

Two years ago the imperial yacht *Livadia* was wrecked. There was,

therefore, a necessity for building another vessel to fulfill the purposes of a sea-going yacht. On this occasion H. M. the Emperor, on the recommendation of the Grand Duke Constantine, accepted the design of a new yacht prepared by Admiral Popoff. In recommending these plans H.I.H. desired to demonstrate by this vessel the capabilities and qualities of the very broad and shallow ships, when the strictly defined problem of carrying heavy pieces of artillery and thick armor on a steady platform, capable of moving with moderate speed, is changed into a wider problem—to attain the greatest steadiness on the sea-way with great speed, not less than that of the yacht which was wrecked. Therefore the problem which was to be fulfilled in the new vessel is exactly the same as that upon the successful solution of which depends the wider range of the development of the means of international communication of the whole world.

In less than one year Mr. Pearce, the head of the most eminent shipbuilding and engineering firm in Scotland, and, as you all know, one of the most enterprising men of the day, after having gone through all the calculations of the vessel, and having satisfied himself as to the principles embodied in her design, has built the new yacht, and now she is so far advanced, that she will be launched next week. Carrying the palace high above the sea admits of having such an amount of light and air in it as could not be attained in sea-going steamers of ordinary form; such a palace built on the ordinary form of vessel would, in a too dangerous degree, have reduced the stability. Three sides and the double bottom will prevent the ship from sinking should she be seriously damaged by collision or stranding. Three sides with a distance between them of not less than 6 feet, and extending all around the ship, are incompatible with the narrowness of the present ordinary vessels. Three independent engines will insure the possibility of navigating the ship to the place of her destination with one or even two engines broken down—an advantage of which not one of the existing steamers can boast. After losing the rudder, the yacht is not left helpless—she can be handled as well by steering her by the side screws.

All investigations and experiments with models of the yacht tended to assure us as to the certainty of anticipated results in regard to the speed of this vessel; whilst the passage through the Bay of Biscay in the equinoctial autumn weather is awaited with greatest interest, not only by us, but by all who are watching the progress of the develop-

ment of steam navigation, as on this voyage the yacht will be the very first vessel of such unusual proportions that will have been brought to face the waves of the Atlantic.

It is true, the *Livadia*—which is the name of the yacht I am speaking of—cannot be considered strictly as being intended for oceanic navigation. Her length as well as breadth is too small for such service, the dimensions of the *Livadia* being determined by the desire to build the cheapest vessel of her kind.

Those acquainted with the question—How much the power of machinery is affected by the size of the vessel which has to be driven will easily understand, that it is impossible to compare the *Arizona* or the *Orient*, whose displacement is eight or nine thousand tons, with the yacht *Livadia*, whose displacement is not greater than four thousand tons. It is impossible, by taking such unequal representatives of two so different species, to compare their efficiency in regard to fuel consumed for a run of a certain distance. A smaller ship, of what-form we take, will always have a disadvantage in point of economy; and this very reason makes the shipowners in advance of other persons to order already steamers like the *Servia* and *City of Rome*. When the same dimensions as those of these last two vessels shall be reached in ships having the form of the *Livadia*, and intended for trans-oceanic service, then the consumption of coal necessary to drive such vessels with the speed of ordinary ones will compare better. However, some exact data in this respect of greatest importance will, no doubt, be obtained from the trials of the yacht. Just on the eve of these trials it would be perhaps premature to speak of, and discuss, the expected performances of the yacht and the vessels of her class more than I have done. In conclusion, I shall refer to the subject of dock accommodation.

Docks capable of lifting vessels of the *Livadia* type for the purpose of painting or repairs, have been already constructed and tested in the Black Sea. The system of single-sided floating docks (known as Messrs. Clark and Stanfield's system), adopted for extremely broad vessels by Admiral Popoff, does not any longer prevent the construction of vessels of any proportions.

The INVOLUTE of the CIRCUMFERENCE of a CIRCLE.

By J. J. Skinner, Ph.D.

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Several years ago I was asked a question like this: Suppose a string 100 feet long to be wound round a vertical cylinder one foot in diameter; if a man takes hold of one end of the string and unwinds it all, by walking around the cylinder, keeping the string stretched, how far will he travel? I solved the general problem as follows:

In the figure let B mark the point where the unwinding begins, and suppose $C\,T$ to represent the part of the string that has been unwound. Denote the length of this by l, denote the radius of the circle by R, and let the *circular measure* of the corresponding angle $B\,O\,C$ be c. Also denote the actual length of the arc $B\,T$ by z. Let $T\,S$ be the differential of z, then the circular measure of the angle $C\,O\,D$ will be dc.

The circular measure of the angle between the tangents $T\,C$ and $S\,D$ is also dc. We shall have

(1) $l = B\,C = R\,c$,

(2) $dz = T\,S = l\,dc$, (in the limit.)

By substitution of (1) in (2), $dz = R\,c\,dc$.

By integration,

$$(3) \qquad z = \frac{R\,c^2}{2} = \frac{l^2}{2\,R};$$

which is a general formula, easy to remember, that agrees with formula (2) given by Prof. D'Auria, on page 46 of the July number of the current volume of this Journal.

By making $2R = 1$, and $l = 100$, we find the answer to the question proposed at the beginning of this article to be 10,000 feet.

The area of the figure $B\,T\,C$ is found with equal facility, as follows:

At the limit we have the area included between $T\,S$ and the

lines $T\,C$ and $S\,D$ equal to $\frac{1}{2}\,dz.\,l$, or, denoting the area $B\,T\,C$ by A, we have $d\,A = \frac{1}{2}\,dz.\,l$.

By substituting in this from (2) and (1) we get

$$d\,A = \frac{R^2\,v^2\,dv}{2};$$

By integrating,

$$A = \frac{R^2\,r^3}{6};$$

which agrees with the formula for A given by Prof. D'Auria on p. 47.

Dust Showers.—M. Daubrée has given an account of the dust showers that were observed from the 21st to the 25th of April, 1880, in the departments of the Lower Alps, Isère and Ain. Heavy dark clouds, resembling a dense yellowish mist, traversed the valleys during the day, depositing a reddish dust with a little water. The neighboring mountains were covered with snow, which assumed a rusty hue to the height of about three kilometres (1·864 miles) and above that height it remained white. The snow, upon melting, left a deposit of a yellowish-brown color, a little redder than limonite dust and almost impalpable. When heated in a tube it blackened, with a disengagement of water and some organic matters of a strong odor. With dilute chlorhydric acid it effervesced strongly, showing a considerable proportion of carbonate of lime. Boiling chlorhydric acid destroyed the yellow color and left a residuum which was fusible under the blow-pipe into a white globule. This residuum contained numerous flakes of white and colored mica, together with some particles which appeared to be feldspar. None of the particles were attracted by the magnet, so that the dust was not probably cosmical, but it resembled in its structure the sand of Sahara. F. de Jussieu reports a similar shower at Autun, on the 15th of April, in which there were traces of iron and perhaps also of lead. A shower occurred in Sicily on the 10th of April, which is said to have deposited considerable quantities of metallic iron covered with a thin layer of oxide. Prof. Orazio Silvestri, of the Meteorological Institute in Catania, gives an account of a shower during the night of March 29—30, in which the dust contained particles of iron, small infusoria and organic molecules. Some of the particles were spherical, as if they had been melted.—*Comptes Rendus, Fortsch. d. Zeit.* C.

The SUMMATION of SERIES WITHOUT the CALCULUS

D'AURIA'S PAPER ON THE "INVOLUTE OF A CIRCLE."[*]

In this paper the summation of two series are required and accepted, the methods of effecting which appear to be insufficiently demonstrated; a little observation, however, will enable the student to obtain the summation of either of these series without resorting to the higher analyses.

The summation of the first is very simple; thus, writing the series:

$$1 + 2 + 3 + \ldots\ldots + (n-3) + (n-2) + (n-1) + n$$

$$n + (n-1) + (n-2) + (n-3) + \ldots\ldots + 3 + 2 + 1$$

the same sum is written a second time in inverse order under the first, and the *two* series added together become

$$n + n + n + n + \ldots\ldots + n + n + n + n$$

when the two series combined evidently become $(n+1)$ terms, multiplying n (the value of the last term) and a single series $= \frac{(n+1)\,n}{2}$.

This summation is so elementary as scarcely to call for a demonstration to any one who would read Prof. D'Auria's article, but the summation of the second series, viz.:

$$(1)^2 + (2)^2 + (3)^2 + (4)^2 + \ldots\ldots + (n-1)^2 + n^2$$

is not so readily effected. In this instance, however, let it be considered that the values $(1)^2$, $(2)^2$, $(3)^2$, $(4)^2$ . . . . be the surfaces of solid plates, the thickness of each plate being unity. Then each plate becomes a square whose sides equal 1, 2, 3, ... n. Suppose these plates to be piled up in a pyramidal form, the base of which is $(n)^2$, on which is placed $(n-1)^2$ and so on to . . $(3)^2$, $(2)^2$, $(1)^2$,] and it is obvious that the sum of the series is included within the solid contents of a pyramid. Such a pyramid of steps will be inscribed within a pyramid of plane sides whose base equals $(n+1)^2$, and whose height $= n+1$, when the line of the corner of the upper face of each of the supposed planes will be in the plane of the sides of the pyramids, and the apex of the pyramid will be formed upon the topmost block $[(1)^2]$ as a little pyramid of itself, having unity for the side of its base and unity as its height.

The cubic contents of this pyramid will then, by the well known properties of a pyramidal body $= (n+1)^2 \times \frac{n+1}{3}$ or equal the

[*] July No. of the JOURNAL OF THE FRANKLIN INSTITUTE.

square of the base multiplied by $\frac{1}{3}$ the height. And the cubic contents of this pyramid exceed that of the sum of the superimposed planes, by the aggregate of the cubic contents of the small pyramids or prisms which lie at the corners or along the sides of the several planes.

Thus there is at the apex, a little pyramid with unity for the side of its base and for its height, which has for cubic contents $= (1)^2 \times \frac{1}{3} = \frac{1}{3}$ cubic, and there is also at each of the four corners of each plane from top to bottom, a little pyramid which has $\frac{1}{2}$ for the side of its base and unity for its height, whose cubic contents for each plane becomes $= 4 \times (\frac{1}{2})^2 \times \frac{1}{3} = \frac{1}{3}$; whence there exists $n + 1$ such solids in excess of the pyramid itself $= \dfrac{n + 1}{3}$

There is also surrounding the four sides of the first plane $= (1)^2$ four triangular prisms each $1 \times \frac{1}{2}$ on their base and 1 high to the apex, the sum of the cubic contents of these four prisms:

$$= 4 \times (1 \times \tfrac{1}{2}) \times \tfrac{1}{2} = 1$$

and surrounding the four sides of the second plane $= (2)^2$ four prisms each $2 \times \frac{1}{2}$ on their face and 1 high to the apex, the sum of the cubic contents of which $= 2 \times (1)^3 = 2$, and finally there is for n planes a number of prisms whose aggregate cubic contents equals

$$1 + 2 + 3 + 4 + 5 \ldots . n.$$

This series is the same as that first considered and its sum $= \dfrac{(n + 1)\, n}{2}$

From all this it is seen that the sum of the series

$$(1)^2 + (2)^2 + (3)^2 + (4) \ldots . (n)^2$$

equals $(n + 1)^2 \times \left(\dfrac{n + 1}{3}\right) - \dfrac{n + 1}{3} - \dfrac{(n + 1)\, n}{2}$

$$= \frac{n^3 + 3\, n^2 + 3\, n + 1}{3} - \frac{n + 1}{3} - \frac{n^2 + n}{2}$$

$$= \frac{2\, n^3 + 6\, n^2 + 6\, n + 2 - 2\, n - 2 - 3\, n^2 - 3\, n}{6}$$

$$= \frac{2\, n^3 + 3\, n^2 + n}{6} = \frac{n^3}{3} + \frac{n^2}{2} + \frac{n}{6}$$

which is Prof. D'Auria's accepted value for the sum of this series.

This summation can be demonstrated or obtained from a general equation founded on considerations of the exponential equation, but the process is decidedly one appertaining to higher algebra, while the calculus gives the result very readily, but the above is easily comprehended by any one whose mathematics are in form for practical application. B.

THE BEAUMONT COMPRESSED AIR ENGINE.

The value of compressed air as a motive power has long been recognized, and many attempts to utilize it in this respect have been made, although hitherto they have not always been attended with practical success. The main difficulty which has stood in the way of inventors and has retarded the progress of the air engine has been that of providing means whereby the full power contained in the air under compression can be utilized economically and at serviceable pressures. Judging from the results of some experimental runs made with an air-driven locomotive which we recently attended, this difficulty would now appear to have been mastered, and highly compressed air to have been rendered practicably available as a source of motive power. This has been effected by Colonel Beaumont, R.E., in an engine which has been lately running in the Royal Arsenal, Woolwich, where its powers have been put to the test of practical work. It is now some four years since Colonel Beaumont first commenced experimenting in this direction, and he has proceeded step by step, improving and perfecting as he went on, until he has at last succeeded in producing the engine in question. The construction of this engine is based upon the principle of utilizing the entire power stored up in compressed air, no matter how high the pressure may be. This is effected by admitting the air into successive cylinders, having different areas, commencing with the smallest, and in making provision by which as the pressure falls in the reservoir the consumption of air can be increased. In other words, the elasticity and the expansive properties of air are taken full advantage of in this engine, just in the same way as the corresponding properties in the vapor of steam are utilized in the compound steam engine—that is, in each case the gases are expanded from the smaller and high-pressure cylinders into the larger and low-pressure cylinders.

In appearance the engine necessarily differs from an ordinary locomotive, the absence of a funnel or other outlet for smoke or steam being the most prominent point of departure. The machine, which is noiseless, more or less resembles a large tank, carried upon wheels, with sundry levers and handles on the top, where the driver is placed. The engine in question, however, is not of the form which is to be

adopted in practice, but is that in which the principle has been finally developed, and is now being demonstrated. The air is first compressed by a stationary engine and machinery into the reservoir of the air engine. In the present instance the compression is effected by the machinery in the Arsenal, by permission of the authorities, who have also consented to Colonel Beaumont carrying out his experiments there, seeing that the principle will find an important application in several directions connected with the government, notably in that of electrically-steered torpedoes. The air is stored in the reservoir under a pressure of 1,000 pounds per square inch, and is delivered thence into the first and smallest cylinder at that pressure. After use there it is expanded into the second and third cylinders in succession, each cylinder having an increased cubical capacity in relation to the one preceding it. From the third cylinder, having there given out its last pound of useful effect, the air is ejected noiselessly into the atmosphere from a small port at the side of the cylinder. The first cylinder being of comparatively small area, difficulty might be experienced in starting the engine on a rising gradient or in the presence of other resistances. To meet this point there is an arrangement for admitting the air at full pressure into the second or intermediate cylinder, so that greater power is thus developed at the first stroke. Another difficulty invariably present when highly compressed air is expanded is the extreme cold produced, which, as is well known, is so great that the moisture in the atmosphere becomes condensed and frozen upon the working parts, thereby contributing to reduce the power and efficiency of the machine, and in time to stop its action. This difficulty is met in Colonel Beaumont's engine by the application of heat, externally, to the compressed air. This is effected by means of a diminutive steam generator which is carried on the framing of the engine. So effectual is this application of a mild heat that the expanded air issues from the exhaust ports quite warm.

With this engine we lately made several runs with very satisfactory results, the machine working smoothly, noiselessly, and at a good speed. A number of runs were effected over a straight length of that part of the Arsenal Railway which runs direct from the proof-butts to the Plumstead entrance of the Arsenal, the length traversed being nearly 700 yards. At starting the gauge showed a pressure of 1,000 pounds per square inch in the air reservoir, and at stopping this had become reduced to 820 pounds, showing that only 180 pounds of pressure had

been consumed in the runs which in the aggregate amounted to a little over three miles. The engine weighs 10½ tons, and a truck containing several passengers which it had hauled weighed about 1½ tons more, making a total of 12 tons. The result of the runs, however, was not considered so good as had been obtained upon previous occasions, as a number of stops were made in order to test the controlling and other qualities of the engine. The engine is arranged so as to be able to make a run of 20 miles with one charge of compressed air. What it really has done, we are informed, has been to haul a gross load of 22 tons for a distance of 11 miles, and the lighter load of 12 tons for over 20 miles, with one charge of air, and which it did under the observation of the Arsenal authorities. From these experiments it was deduced that the engine will take three tons one mile with the expenditure of one cubic foot of compressed air. There can be no doubt that the engine so far has worked most satisfactorily, and there can be as little doubt that the new pattern engine, which we understand will soon be running on the Edinburgh and Portobello tramway, will prove as successful. If cost of production, maintenance and working is found to be low, other things being equal, there is a wide future before this system. Not only will it be applicable for tramway service, in which connection it has been mainly developed by Colonel Beaumont, but it will probably be found capable of working the traffic of our underground railways. This would be a great boon both to the railway passengers and to the company's servants. It will be seen that this system of applying compressed air differs from any that has been hitherto in use, inasmuch as it avoids the loss entailed by the use of a reducing valve and the cooling of the air by expansion. The arrangement appears to enable a much greater amount of power to be realized out of a given quantity of energy stored up than hitherto, and the success of the system, so far, entitles it to the consideration of those who are connected with our tramways and railways.—*London Times.*

Treatment of Frosted Potatoes.—The severe winter in France froze such large quantities of potatoes that some of the farmers were induced to experiment upon them, and they found that if the frozen potatoes were thoroughly washed and then dried slowly, in a current of air with a temperature but slightly above the freezing point, all evidences of the frost would be removed.—*Chemical Journal.*

NEW APPLICATIONS OF THE DYNAMO-ELECTRIC CURRENT.

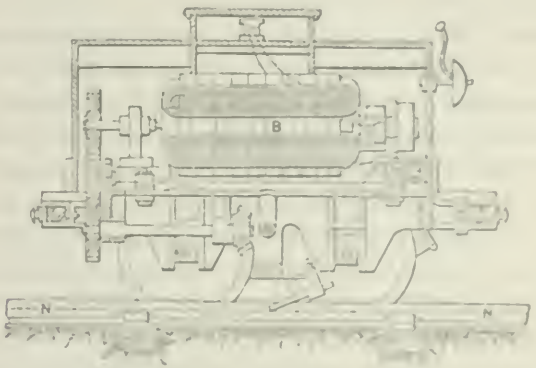
The idea of superseding the steam locomotive by an electric engine is by no means a novel one; but it was never practically realized until last year, when Dr. Werner Siemens built and operated an electric tramway in the grounds of the Industrial Exhibition at Berlin. In connection with the history of this subject it is worth while to mention that an attempt was made to devise an electric locomotive in America some thirty-three years ago. The *Scientific American* for September 25, 1847, contains a description of a new mode of railway propulsion, the joint invention of Mr. Lilly and Dr. Colton of Pittsburgh, Pennsylvania. "The machine," says this account, "is a small locomotive, and is placed upon a circular railway, around which it is driven by electricity. The power is applied not to the locomotive, but to the *track*, in a very curious manner. Two currents of electricity, negative and positive, are applied to the rails, and by them communicated to the engine. The latter is provided with two magnets, which, by a process of alternate attraction and repulsion, drive the car over the track. A piece of lead is placed on the locomotive, making in all a weight of 10 pounds, and on the application of the battery the machine moved with astonishing rapidity up a plane inclined about five degrees." In this apparatus the current was supplied by a battery, a fact which, together with the imperfect state of electric science at the time, doubtless caused its failure.

Another claimant for priority of invention of the electric railway is M. Boué, *sous-intendant militaire* at Belfort, in France. This gentleman took out a French patent in 1878 for the propulsion of carriages on a railway by means of electricity; and not only does the patent describe a means for driving a single train of cars, but also a vibratory apparatus whereby the power of the current may be distributed to several separate trains so as to propel them all. Perhaps, too, we ought to mention that Mr. Edison has of late been relieving his severer labors by the erection of an electric railway, on which it is his delight to whisk his admiring visitors along. Curiously enough he also intends to build a line at a very steep gradient (1 in 6) in order to show the capabilities of his electric railway for overcoming inclines. We say

curiously enough, because that is one of the purposes which Dr. Werner Siemens has expressly stated that the new electric train would be adapted to.

Historical mention is justly accorded to the pioneers of a new invention, though the chief merit rests with him who makes it a success.

To Dr. Werner Siemens belongs the honor of recognizing that the improved means now at our disposal for generating electricity and applying it to the transmission of power are sufficient to operate an electric railway on a practical scale.



The Berlin railway was a narrow gauge line, laid down in a circle 900 yards long. A train of three or four carriages was placed upon it, and on the first carriage a medium-sized dynamo-electric machine was fixed to the axle of one pair of wheels in such a manner as to rotate the wheels when the armature of the machine was rotated by the passage of a current through its coils. The rails were laid upon wooden sleepers which even in wet weather insulated the rails very well for this length of line. A third rail between the other two, and it was by this central conductor that the current was led from the generating machine placed at one terminus of the line. The current was drawn from this rail to the armature of the machine on the locomotive by means of a brush of copper wires; and after traversing the coils of the armature it was led to the axle of the driving wheels which was insulated from the body of the car, and thence by the driving wheels to the outer rails, and by them back to the dynamo machine at the terminus. The annexed figure represents a section through the locomotive, showing the dynamo-electric machine B and the central rail N with the metal brush for abducting the current.

Between twenty and thirty persons could be accommodated on the train at a time, including the conductor, who rode on the first carriage; and during the course of the summer no fewer than 100,000 were conveyed over the line at a speed of from 15 to 20 miles an hour. Crowded trains left the stations every five or ten minutes, and a considerable sum was earned in this way for the benefit of charitable institutions. The locomotive was capable of exerting five horse power, and instead of being fitted with a steam valve like a locomotive to start or stop it, it was simply provided with a commutator for closing or opening the circuit of the current.

"It is," says Dr. C. W. Siemens, "a remarkable circumstance in favor of the electric transmission of power, that while the motion of the electro-magnetic or power-receiving machine is small, its potential force is at its maximum, and it is owing to this favorable circumstance that the electric train starts with a remarkable degree of energy. With the increase of motion the accelerating power diminishes until it comes to zero, when the velocity of the magneto or driven machine becomes equal to that of the dynamo or current-producing machine. Between the two limits of rest and maximum velocity the driving power regulates itself according to the velocity of the train; thus, on an ascending gradient the speed of the train diminishes, but the same effect is automatically produced which results from the turning on of more steam in the case of the locomotive engine. When running on the level, the velocity of the train should be such that the magneto-electric machine should make one-half to two-thirds of the number of revolutions per minute of the dynamo-electric machine. When descending, the speed of the magneto-electric machine will be increased in consequence of the increased velocity of the train, until it exceeds that of the dynamo-electric machine, from which moment the functions of the two machines will be reversed; the machine on the train will become a current generator, and pay back as it were its spare power into store, performing at the same time the useful action of a brake in checking further increase in the velocity of the train. If two trains be placed upon the same pair of rails, the one moving upon an ascending portion, the other upon a descending portion of the same, power will be transmitted through the rails from the latter to the former, and they may, therefore, be considered as connected by means of an invisible rope."

With regard to the relations of work done to energy expended on

the electric railway, the proportion of power actually transmitted varies with the speed of the train, and reaches a maximum when the angular velocity of the armature of the machine on the train is about two-thirds that of the armature of the current generator. Under this condition it is found in practice that something over 50 per cent. of the motive power of the stationary engine driving the generator is utilized in drawing the train.

It is not to be expected that the electric locomotive will compete with the steam locomotive on long lines of railway, any more than the electric light will at present rival gas for general use, but it may prove very serviceable under special circumstances, and on short lines. For steep gradients, tramways in mines, docks, large works, or cities, it is particularly well adapted, owing to its freedom from noise or noxious fumes. It is also well adapted for the transmission of letters along subterranean tubes; and we understand that experiments are being made in Paris with a view to supplanting the pneumatic system of carrying letters by an underground "electric post."

A more important project, however, is the scheme of Dr. Werner Siemens for an elevated tramway to connect one end of the city of Berlin with the other. It is proposed to have two separate lines, one for the going and the other for the return journey. The rails are to be 3 feet 3 inches apart, and only two rails will be required for each line, the current coming from the terminal engine by one line, and returning by the other. Each train has fourteen narrow cars, four to convey standing passengers, and ten for sitting passengers. A 60-horse power engine will be stationed at one end of each line, and the speed will be 20 miles per hour. A good deal of opposition to the project has been offered by the owners of property along the route under the impression that it will depreciate the value of their houses, and a commission has been appointed to examine these objections.

The freedom of the electro-locomotive from smoke is of great importance in passing through a long adit or tunnel, and it is interesting to learn that the administration of the St. Gothard Tunnel seriously contemplate its application to the conveyance of their trains through that gigantic tunnel. Existing circumstances are in this case favorable to the employment of electric power, for at both ends of the tunnel turbines of enormous aggregate power were established to assist in boring, and still stand ready for use. All that has to be done, therefore, is to insulate the rails, and connect up dynamo-electric

machines of sufficient power to the turbines and the train. Instead of insulating one of the rails, it might be advisable to convey the current by a conducting rope resting on wooden or glass supports in such a manner that it can be picked up by the train as it passes, and run over one or more contact pulleys connected to the armature of the machine carried by the train, then deposited again on its insulating supports. In this way, no doubt, the insulation of the rails could be avoided, but it remains to be determined by experiment whether the high velocity of the train would not render such a plan impracticable. —*Engineering.*

Electric Synchronism of Motors and Receivers.—M. Deprez was requested, by one of the French railway companies, to transmit to the interior of an experimental car a rotary movement rigorously identical with that of the wheels of a locomotive, which was attached to a train of which the car formed a part. After having constructed the car with great difficulty, by means of ordinary mechanical contrivances, he thought of the following simpler plan, which proved to be entirely effectual. Two commutators are attached to the arbor of the transmitter; each of them reverses the current twice in one revolution of the axle, but the positions of the arbor corresponding to these inversions follow each other at intervals of a quarter of a revolution. The receiver is composed essentially of a permanent magnet or electro-magnet, between the branches of which are placed two straight electro-magnets, susceptible of rotation around an axis which coincides with the axis of the magnet. If currents of equal intensity are passed into each of the electro-magnets, the right angle which they form places itself in such a position of equilibrium that it is bisected by the straight line which joins the poles of the permanent magnet. Moreover, to to each of the combinations of the transmitter there is one and only one corresponding position of equilibrium for the electro-magnets of the receiver. Therefore, if the transmitting arbor is turned the resulting currents will impress upon the receiving arbor a rotary movement, which will have exactly the same velocity and the same direction as that of the transmitter. The conservation of the angular velocity has been rigidly tested for speeds varying from one to 2400 turns per minute.—*Comptes Rendus.* C.

ON A FOURTH STATE OF MATTER.*

By W. Crookes, F.R.S.

As I find that many scientific men are in doubt as to whether matter has been shown to exist in a state beyond that of gas, I will now endeavor to substantiate my position.

I will commence by explaining what seems to me to be the constitution of matter in its three states of solid, liquid and gas.

1. First as to solids: These are composed of discontinuous molecules, separated from each other by a space which is relatively large—possibly enormous—in comparison with the diameter of the central nucleus we call *molecule*. These molecules, themselves built up of *atoms*, are governed by certain forces. Two of these forces I will here refer to—attraction and motion. Attraction when exerted at sensible distances is known as gravitation, but when the distances are molecular it is called *adhesion* and *cohesion*. Attraction appears to be independent of absolute temperature; it increases as the distance between the molecules diminishes; and were there no other counteracting force the result would be a mass of molecules in actual contact, with no molecular movement whatever—a state of things beyond our conception—a state, too, which would probably result in the creation of something that, according to our present views, would not be *matter*.

This force of cohesion is counterbalanced by the movements of individual molecules themselves, movements varying directly with the temperature, increasing and diminishing in amplitude as the temperature rises and falls.

The molecules in solids do not travel from one part to another, but possess adhesion and retain fixity of position about their centres of oscillation. Matter, as we know it, has so high an absolute temperature that the movements of the molecules are large in comparison with their diameter, for the mass must be able to bear a reduction of temperature of nearly 300° C. before the amplitude of the molecular excursions would vanish.

The state of solidity therefore—the state which we are in the habit

* A paper read before the Royal Society, June 19th, 1880.

of considering *par excellence* as that of *matter*—is merely the effect on our senses of the motion of the discrete molecules among themselves.

Solids exist of all consistences, from the hardest metal, the most elastic crystal, down to thinnest jelly. A perfect solid would have no viscosity, *i. e.*, when rendered discontinuous or divided by the forcible passage of a harder solid, it would not close up behind and again become continuous.

In solid bodies the cohesion varies according to some unknown factor, which we call chemical constitution; hence each kind of solid matter requires raising to a different temperature before the oscillating molecules lose their fixed position with reference to one another. At this point, varying in different bodies through a very wide range of temperature, the solid becomes liquid.

2. In liquids the force of cohesion is very much reduced, and the adhesion or the fixity of position of the centres of oscillation is destroyed. When artificially heated, the inter-molecular movements increase in proportion as the temperature rises, until at last cohesion is broken down, and the molecules fly into space with enormous velocities.

Liquids possess the property of viscosity—that is to say, they offer a certain opposition to the passage of solid bodies; at the same time they cannot permanently resist such opposition, however slight, if continuously applied. Liquids vary in consistency from the hard, brittle, apparently solid pitch, to the lightest and most ethereal liquid capable of existing at any particular temperature.

The state of liquidity, therefore, is due to inter-molecular motions of a larger and more tumultuous character than those which characterize the solid state.

3. In gases the molecules fly about in every conceivable direction, with constant collisions and enormous and constantly varying velocities, and their mean free path is sufficiently great to release them from the force of adhesion. Being free to move, the molecules exert pressure in all directions, and were it not for gravitation they would fly off into space. The gaseous state remains so long as the collisions continue to be almost infinite in number, and of inconceivable irregularity. The state of gaseity, therefore, is pre-eminently a state dependent on collisions. A given space contains millions of millions of molecules in rapid movement in all directions, each molecule having millions of encounters in a second. In such a case, the length of the mean free path of the molecules is exceedingly small compared with

the dimensions of the containing vessel, and the properties which constitute the ordinary gaseous state of matter, which depend upon constant collisions, are observed.

What, then, are these molecules? Take a single lone molecule in space. Is it solid, liquid or gas? Solid it cannot be, because the idea of solidity involves certain properties which are absent in the isolated molecule. In fact, an isolated molecule is an inconceivable entity, whether we try, like Newton, to visualize it as a little hard spherical body, or with Boscovich and Faraday, to regard it as a centre of force, or accept Sir William Thomson's vortex atom. But if the individual molecule is not solid, *à fortiori* it cannot be regarded as a liquid or gas, for these states are even more due to inter-molecular collisions than is the solid state. The individual molecules, therefore, must be classed by themselves in a distinct state or category.

The same reasoning applies to two or to any number of continuous molecules, provided their motion is arrested or controlled, so that no collisions occur between them; and even supposing this aggregation of isolated non-colliding molecules to be bodily transferred from one part of space to another, that kind of movement would not thereby cause this molecular collocation to assume the properties of gas; a molecular wind may still be supposed to consist of isolated molecules, in the same way as the discharge from a mitrailleuse consists of isolated bullets.

Matter in the fourth state is the ultimate result of gaseous expansion. By great raréfaction the free path of the molecules is made so long that the hits in a given time may be disregarded in comparison to the misses, in which case the average molecule is allowed to obey its own motion or laws without interference; and if the mean free path is comparable to the dimensions of the containing vessel, the properties which constitute gascity are reduced to a minimum, and the matter then becomes exalted to an ultra-gaseous state.

But the same condition of things will be produced if by any means we can take a portion of gas, and by some extraneous force infuse order into the apparently disorderly jostling of the molecules in every direction, by coercing them into a methodical rectilinear movement. This I have shown to be the case in the phenomena which cause the movements of the radiometer, and I have rendered such motion visible in my later researches on the negative discharge in vacuum tubes. In one case the heated lampblack and in the other the electrically excited

negative pole supplies the *force majeure* which entirely or partially changes into a rectilinear motion the irregular vibration in all directions; and according to the extent to which this onward movement has replaced the irregular motions which constitute the essence of the gaseous condition, to that extent do I consider that the molecules have assumed the condition of radiant matter.

Between the third and fourth states there is no sharp line of demarcation, any more than there is between the solid and liquid states, or the liquid and gaseous states; they each merge insensibly one into the other. In the fourth state properties of matter which exist even in the third state are shown *directly*, whereas in the state of gas they are only shown *indirectly*, by viscosity and so forth.

The ordinary laws of gases are a simplification of the effects arising from the properties of matter in the fourth state; such a simplification is only permissible when the mean length of path is small compared with the dimensions of the vessel. For simplicity's sake we make abstraction of the individual molecules, and feign to our imagination *continuous* matter of which the fundamental properties—such as pressure varying as the density, and so forth—are ascertained by experiment. A gas is nothing more than an assemblage of molecules contemplated from a simplified point of view. When we deal with phenomena in which we are obliged to contemplate the molecules individually, we must not speak of the assemblage as *gas*.

These considerations lead to another and curious speculation. The molecule—intangible, invisible, and hard to be conceived—is the only true *matter*, and that which we call matter is nothing more than the effect upon our senses of the movements of molecules, or, as John Stuart Mill expresses it, "a permanent possibility of sensation." The space covered by the motion of molecules has no more right to be called matter than the air traversed by a rifle bullet can be called lead. From this point of view, then, matter is but a mode of motion; at the absolute zero of temperature the inter-molecular movement would stop, and although *something* retaining the properties of inertia and weight would remain, *matter*, as we know it, would cease to exist.

Aerial Photographs.—By placing a camera in an aperture in the bottom of the car of a balloon very successful negatives have been recently obtained in Paris of the landscape below.

HOLMAN'S NEW COMPRESSORIUM AND MOIST CHAMBER.

By JOHN A. RYDER,
Of the United States Fishery Commission.

In working with living animal forms suitable for the elucidation of some of the principal doctrines of life, any contrivance which will render the study easier, and hence more profitable and economical of time, should be hailed with delight by the working microscopist. Such a labor-saving device is represented in the accompanying cut, Fig. 1, of Mr. D. S. Holman's new compressor. This apparatus

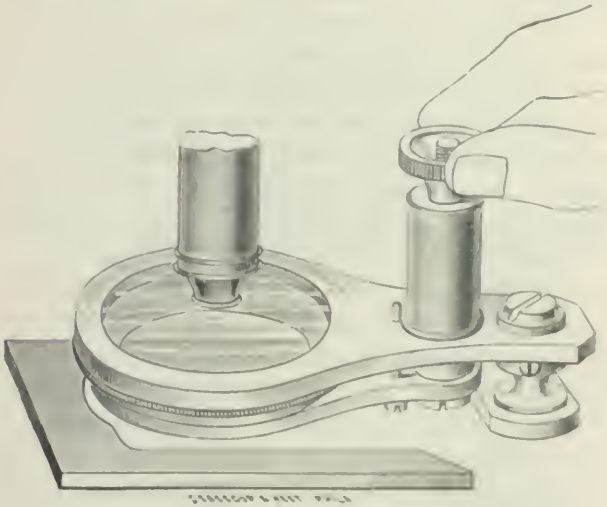


Fig. 1.

differs from all other compressors in being so arranged that the mica cover is fixed and immovable, while the lower, thicker plate of glass is moved up and down by means of a screw nut and spiral spring, an arrangement which enables the student to adjust the apparatus so as to apply *with certainty* any degree of pressure upon any soft object without risk of breaking large and expensive cover glasses, crushing the object unexpectedly, or injuring high-power lenses. The writer by

its means was enabled to study with great deliberation and certainty the internal anatomy of the larva of the plumed crane-fly (*Corethra plumicornis*). In this case the pressure could be so nicely adjusted as not to disturb in the slightest degree the normal physiological actions of the larval fly; the physiological action of the heart could be readily studied, as well as the significance of the so-called apolar ganglion cells of that organ appreciated. Every life process, in short, was visible through the transparent body of the creature, so that if *well* studied by the help of this apparatus, the student will have acquired a mental image or epitome of the morphology and physiology of that great group of jointed animals, the *articulates* of the naturalist.

Equally good results were got by its use in studying the embryology of the shad, where it revealed to the writer, and for the first time to science, the presence of a so-called polar vesicle in the earliest stages of development.

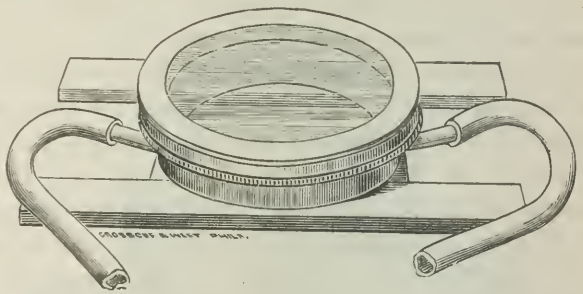


Fig. 2.

In Fig. 2 we have a combination of the familiar animalcule cage and the siphon slide, also designed by Mr. Holman. The edge of the cover or cap is beveled, so that by rotating it against the inflow and outflow tubes of the siphon arrangement, a very convenient and effective compressor is obtained. The apparatus is equally as valuable as the compressor before described, because of the certainty with which one can gauge the amount of pressure which is applied; also on account of the facility with which water may be renewed in it when used as a "moist chamber" for studying growing fungi, without in the slightest degree disturbing these delicate plants. The value of the apparatus is further enhanced by the facility with which it may be used as a siphon slide for keeping aquatic larvæ, worms, etc., alive for a lengthened period for study or exhibition. It is equally useful as a

dry compressor for holding, studying and drawing minute soft-bodied insects in the living state. These useful pieces of apparatus should be found upon the table of every working microscopist, where every day's use will demonstrate their indispensibility. It was in one of Mr. Holman's siphon slides, right under the microscope, that the writer successfully hatched young shad, a feat never before performed with the eggs of fishes.

ON THE ARTIFICIAL FORMATION OF THE DIAMOND

By J. B. Hannay, F.R.S.E., F.C.S.

Paper communicated to the Royal Society by Prof. G. G. Stokes, L.L.D.

In a preliminary notice, which the Royal Society has done me the honor of publishing in the "Proceedings," I gave a very short sketch of the work I have done which led me to a reaction whereby hard crystalline carbon has been produced. I have now the honor of laying a detailed account of the methods and results before the Society. As far back as September, 1879, I was searching for a solvent for the alkali metals, and tried experiments with many liquids and gases, but invariably found that when the solvent reached the permanently gaseous state chemical action ensued. This was the case even with hydrocarbons, the metal combining with the hydrogen and setting free the carbon. Paraffin spirit, boiling at 75°, was first used in experimenting, and the spirit contained a considerable amount of olefines; but even these unsaturated hydrocarbons seemed to be split up in like manner. The experiments were conducted in thick tubes from 1 to 1·5 millims. internal, and 10 to 15 external, diameter, and made of hard glass. In some cases when the carbon was set free, a considerable proportion of the hydrogen seemed to have combined with the higher olefines and paraffins, rendering them gaseous, most of the gas, however, being formed by the reaction discovered by Thorpe and Young, where a high paraffin splits up into lower olefines and paraffins. This reaction, I would remark in passing, is not always the only one to take place, as a mixture of lower paraffins and olefins on being heated under very high pressure sometimes yield a small quantity of a higher or even nearly solid paraffin, as well as gaseous products. An attempt was made to obtain solid paraffin in quantity by this method, but only traces were obtained white enough for use.

The alkali metal which decomposes the hydrocarbon retains a quantity of pure hydrogen, which may be seen by exhausting it by the Sprengel pump. A piece of sodium was exhausted in the molten state for five hours by the Sprengel pump, and when no more hydrogen had been evolved for an hour, a piece was placed in a tube with paraffin spirit and heated for two hours, and when a considerable quantity of carbon was deposited, as much of it was removed as could be conveniently obtained and again exhausted, when 32 times its volume of hydrogen was extracted from it. This was repeated several times, and quantities of hydrogen, varying from 17 to 25 times the volume of the sodium, obtained. The carbon deposited on the tube is of a hard scaly nature, and when the sodium is slowly oxidized and dissolved in water, some very hard scales of carbon are often obtained. This was then the reaction on which my work was built. As potassium is a metal of stronger affinities, I thought that an examination of its action on paraffin would yield somewhat better results, but in this I was disappointed. Sometimes its action was very great, but it seemed to combine with some of the substance in the tube, and formed black compounds, having no hard carbon amongst them. Some of the experiments did yield a little, but on the whole it was not so good as sodium. Lithium was next tried and yielded results which were much more hopeful. When the same paraffin spirit was used the lithium floated on it, but by melting the metal in the bottom of the tube it adhered to the sides, and did not float to the top unless any portion became detached. The appearance shown by lithium is sometimes very beautiful, a small globule of the metal when it has liquefied showing, before it begins to act energetically upon the hydrocarbon, a very beautiful play of colors. After this has gone on for a little a more rapid reaction sets in as the temperature rises, and carbon is deposited somewhat more plentifully. Sometimes a piece of the metal will float until it becomes coated with carbon and it then sinks. The carbon so obtained is harder than when sodium is employed, and will often scratch glass easily. I thought that if I could by increased temperature dissolve the nascent carbon in the metal I might obtain diamond; but after very many trials I did not succeed in doing so. Many of my scientific friends who had witnessed my experiments thought that a gaseous solvent for carbon might be found, and as this was the direction of my general work, I abandoned these metallic experiments and went into a more direct examination of the question

of gaseous solution. As by far the greater number of substances with which we are acquainted are found by the intervention of water and are only soluble in water, I thought that an examination of the solvent effects of water under different circumstances would be likely to yield important results. I found that hard glass tubes resisted the action of water after it had passed its critical point for a time sufficiently long to enable an observer to see whether any great change had taken place in the solution contained in the tube. By these means it was found that many chlorides, sulphates, and nitrates were as soluble in water-gas as in water, if not more so, and that at least no sudden change of solubility was observable at the critical point. By such a process, however, only qualitative results could be obtained, and a series of experiments was tried, using various volumes of water with a fixed proportion of silica in iron tubes, and the solvent power of the water estimated in a more accurate manner. An account of this work will, I hope, be laid before the Society shortly; in fact, as soon as I have the necessary time for completing the work and writing it up. The general result obtained from these experiments was that the solvent power of water was found to be determined by two conditions: 1st. Temperature or molecular *vis viva*; and 2d. Closeness of the molecules or pressure, which seems to give penetrative power. From these observations it will be seen that if a body has any solvent action on another and does not act upon it chemically, such solvent action may be indefinitely increased by indefinitely increasing the temperature and pressure of the solvent. In nature, the temperature has been at one time higher than we can obtain artificially, and the pressure obtained by a depth of 200 miles from the surface is greater than can be supported by any of the materials from which we can form vessels. It will thus be seen that, whereas in nature almost unlimited solvent power could be obtained, we are not as yet able to reproduce these conditions artificially. Could pressure alone increase solvent power then much might be done, but pressure only acts by keeping the molecules close together when they have great *vis viva*, and this latter is only obtained by high temperature.

As glass tubes were quite out of the question when a red heat and very high pressure were required, iron tubes were resorted to, and a series of attempts made to dissolve carbon by various gaseous solvents. The difficulty of closing iron tubes as compared with glass tubes caused me to try various methods, which I shall describe here. Tubes were made

of strong hydraulic tubing, 20″ long, 1″ thick, and ½″ bore. These were fitted with a plug, screwed with a strong screw fitting very well. There was placed in the tube some powdered charcoal from which all the inorganic matter had been removed by immersion in hydrochloric and hydrofluoric acids and washing with water, and then sufficient paraffin spirit to fill the tube two-thirds of its volume. The plug was screwed in with a lute composed of silicate of soda and manganese dioxide, but after heating the tube in a reverberatory furnace for four hours it was found to be impossible to remove the plug, so the end had to be bored out. There was neither liquid nor gas in the tube, the luting having leaked. Another tube similarly filled was fitted with a plug with a copper washer, the end of the tube, plug, and washer being polished, but this also leaked and no result was arrived at. Baryta, clay, asbestos, and other substances, wet with silicate of soda, were all tried with the same result—leakage. A silver washer kept comparatively tight, but only on one occasion. It was thus seen that screw-closing would give no reliable results, so another method was tried. A ball of iron, fitting the tube tightly, was placed in it after the materials had been introduced. The end of the tube was then narrowed by compression between rollers and turned smooth inside. The iron ball was then drawn up by a wire attached and luted by silicate of soda and fine manganese dioxide. It was expected that the pressure would only serve to make the closing more secure, but, on heating, the iron yielded and the ball was driven out with a loud explosion. After trying several other methods of closing—outside screwing and filling the mouth with molten metal on the top of a clay plug being amongst them—I came to the conclusion that nothing would suffice but welding up the open end. This has been, when carried out efficiently, invariably successful, and in all my later experiments I have used it alone. It requires great skill on the part of the workman, and it is only one man in a hundred who can perform the operation with invariable success. The furnace used in these experiments was a reverberatory one, 6 feet long (internal measurement) and 2 feet broad; fire-place, 15 inches; bridge, 9 inches; hearth, 4 feet. The roof sloped down towards the flue and the spent gases had exit at the level of the hearth, thus carrying the flame down as it receded from the fire, in order to have the hearth of one temperature. The walls were 13 inches thick, and the roof formed of 4-inch fire-clay covers.

Three tubes, 20″ × 1″ × ½″ bore, were filled as follows:

No. I. 3 grms. sodium, ¾ full paraffin spirit.
" II. " " ½ " "
" III. " " ¼ " "

On heating them in the reverberatory furnace, No. I exploded before a visible red-heat had been obtained, so the temperature was not allowed to rise any higher, and Nos. II and III allowed to lie for four hours and then slowly cooled. On being bored open next day, No. II contained a little scaly carbon, but No. III contained almost none, and nearly all its liquid had been converted into gas, which rushed out on boring it open. It was noticed by the workmen that the inside of the tube was harder to bore than the outside, and I thought, as I found out afterwards rightly, that the iron had been carbonized and converted into steel. It seemed, then, that the free carbon had been taken up by the iron. The same two tubes were welded up again, rather more than half-full of liquid, and slowly heated, but before they came to as high a temperature as they had been subjected to formerly, they exploded together. Two more were filled, welded, and heated, but again they burst simultaneously. It appeared, then, that those tubes were too weak, so two were made 20″ × 2″ × ½″ bore. On trying to weld them when two-thirds full, the liquid got hot, and gave off enough vapor to carbonize the white-hot plug and made a bad weld, so that they had to be kept cool by trickling water upon them immediately below the hot part. Several tubes were lost in closing before the workman became deft enough at closing them. Two were at length obtained well closed, and were heated, but again, before a red-heat was reached, they exploded simultaneously, smashing the roof of the furnace. It seemed on examining the tubes that one had gone off first, and struck the other such a blow as caused it to burst, as one had a mark near the middle as from a blow with a hammer, and was bent a little. It became plain, then, that two should not be heated together, at least where they might strike each other on explosion. Then, again, as the iron took up the carbon set free, I considered that the reaction might be favored by adding some carbon to the liquid in the form of lamp-black, so that the liquid would be kept always saturated. A tube, 20″ × 2″ × ½″ bore was filled, as before, to about three-fourths of its volume, and about half a gram of lamp-black added. This was heated to just below a red-heat for six hours and allowed to cool slowly. On being cut open there was a considerable yield of scaly carbon, and

the sodium, on being dissolved, left a few pretty hard scales, along with ferric oxide, spongy iron, etc. This was encouraging, and another tube was filled in the same way, but it burst on heating. An experiment was then tried with paraffin spirit and lamp-black alone, only about 2 grms. of lamp-black being added to the tube, three parts filled with hydrocarbon. This experiment went successfully, and on opening the tube after the outrush of gas it was found that nearly all the lamp-black had been absorbed by the iron. This showed that my conjecture was right about the disappearance of the carbon. Two divisions were then built upon the furnace-hearth, so as to divide it into three spaces, and three tubes of the above dimensions, and filled as follows, were put in them:

No. I. 3 grms. naphtha, $\frac{1}{2}$ grm. lamp-black, $\frac{1}{2}$ full paraffin spirit.
" II. " " " " $\frac{2}{3}$ " "
" III. " " " " $\frac{3}{4}$ " "

On heating, No. II burst with a loud explosion, but did not harm Nos. I and III, but on opening these next day they were found to have leaked, so that there may have been no pressure inside them at the time. Other two, two-thirds filled with liquid and solids as above, also burst; but as I was absent I do not know at what temperature they were.

It seemed plain that the tubes were much too frail, and although they were made from "Lowmoor" iron, well hammered, and the tube bored out of the solid, they invariably burst lengthwise, showing a reedy structure. I determined then to try tubes on the coil principle; so two were constructed out of the toughest bar iron, made solid, and bored out afterwards. The dimensions were $20'' \times 2\frac{3}{4}'' \times \frac{1}{2}''$, and they were heated to a just visible red-heat, and contained 3 grms. sodium, $\frac{1}{2}$ grm. lamp-black, and two-thirds full of paraffin spirit. The heat was kept up eight hours, and the tubes allowed to cool in the furnace. Both kept tight, and yielded some hard scaly carbon, but nothing else. One was tried with lithium, and a better yield of carbon obtained, and it was also harder. Two more tubes of the same dimensions, with lithium, burst, and so were lost. It now became evident that much stronger tubes were necessary for this reaction, or that some other reaction would require to be found.

I would here mention a fact which, although not directly connected with our subject, is of great interest to students of chemical physics. When introducing the alkali metal into the tube it was found necessary

to push it down with a rod, and in one or two cases when I had mislaid the iron rod for the purpose I used a glass rod, of which the end had not been rounded by fusion. In consequence, some small particles of glass became detached, and being lead glass they were heated to such a temperature that they were softened, and in some cases completely melted by the heat. Whenever this had taken place the piece of glass had cavities in it, and these cavities were partially filled with liquid or compressed gas, generally with a portion of each. In the same piece of glass the bubbles were of different size, and often filled to different heights with liquid, just as we find liquid carbonic acid and water filling in different proportions the cavities in the same quartz crystal. How these cavities in the glass are formed, and how the liquid gets into them, I cannot at present determine, but even little spheres of glass purposely introduced likewise developed cavities containing liquid on being fused under pressure. As this is a part of the subject I am investigating, the results being easily produced, I shall reserve its full discussion until I have examined it from various points of view, and varying the substances employed. I think it right to mention it here, however, as I have so little leisure and so many interesting discoveries just touched upon, and each one more tempting as a field of labor than the other, that it may be some time before I can have full data on the subject.

The iron used in making the tubes is what is known as "Lowmoor" iron, a very pure and strong quality, and a portion removed from the interior of a tube which has been used gave, on analysis, 2·17 per cent of carbon, showing to what an extent carbonization had gone on.

Having obtained results from this process of a kind which showed that diamond was unlikely to be formed by its agency, I reverted to the original idea of solution of carbon in a gaseous menstruum, and from some experiments I had been carrying on with the view of finding some commercial use for "bone oil," I concluded that the distillate from bone oil containing the nitrogenous bases would be most likely to yield such a solvent. Bone oil, the nitrogenous distillate obtained in the manufacture of bone char, and for a plentiful supply of which I am indebted to Messrs. John Poynter and Sons, of Glasgow, was distilled, and the portion boiling between 115° and 150° was taken and rectified over solid caustic potash, and latterly over sodium. When satisfied that it was free from moisture, oxygen, and sulphur, a tube, 24″ × 20″ = ¼″ bore, was three parts filled, and some charcoal powder

added, and the whole welded up solid. I found that the nitrogenous liquid was even worse to work with than the hydrocarbon, as on coming into contact with the hot iron it burnt it away at once, and as the tube was of great diameter it was extremely difficult to keep the lower part cool. For welding it had to be arranged so that it was standing in of tub of ice, and the top projecting through the bottom of the forge, and heated until it was at a welding heat, with as little delay as possible. When a tube was obtained welded up solid it was heated to a dull red-heat for 14 hours, and allowed to cool; on opening the tube there was a very great out-rush of gas, and the carbon was to a certain extent dissolved, and some minute portions of it very hard. Still, under the microscope it presented little difference in appearance from the wood charcoal employed, some of the features, however, being obliterated, and it had a bright appearance. Another tube of the same dimensions and contents was closed up in the same manner, but after eight hours' heating it burst with a loud explosion. I had noticed that a tube which had been once used and been partially carbonized would not stand a second heating, and for this reason I had no belief in the power of cast-iron or steel to withstand the great pressure at a red-heat. Nevertheless, as many of my friends had urged upon me to try these materials, I had a cast-iron tube made, $3\frac{3}{4}'' \times 24'' \times \frac{3}{4}''$ bore, and filled two-thirds of its volume with bone oil distillate and carbon, and then welded up. We succeeded after a little trouble in making a good weld, and the tube was then slowly raised to a dull red-heat in the furnace. It had not been heated for more than an hour when it exploded with a great noise, and knocked down the back and one of the ends of the furnace, leaving the whole structure a wreck. The tube had broken into small fragments, and was quite unlike the malleable iron tubes which generally tore up. Thinking that it was perhaps a bad casting, I tried another, but it leaked all over, and emptied itself before the temperature was nearly up. A third tube of the same material burst like the first, but as I had built up the furnace with large blast-furnace blocks, it was not blown down. Cast-iron being inadmissible, experiments were then made with steel. I had several tubes made of this material by the best firms in the kingdom—made by the three methods, Bessemer, Siemens, and the crucible method—but they had the same faults as cast-iron, although to a less degree The difficulty in making a good weld in cast-iron and steel tubes makes their employment in such experiments as these a matter of incon-

venience. Out of five tubes made of steel, some of which were made of the very toughest material manufactured by Messrs. Cammell and Co., only one held in the substance completely. Three burst in the furnace, and one had leaked by its porosity. The top of the furnace, by the continued shocks of explosions, fell in at the bursting of the last of the steel tubes. The continued strain on the nerves, watching the temperature of the furnace, and in a state of tension in case of an explosion, induces a nervous state which is extremely weakening, and when the explosion occurs it sometimes shakes one so severely that sickness supervenes.

It appeared that as the bone oil had so hardened the carbon, if it acted upon nascent carbon it might harden it so much as to produce diamond. An experiment was accordingly tried in which bone oil distillate and paraffin spirit were mixed, so that when an alkali metal was made to act upon it the decomposition of the hydrocarbon might yield carbon which would be crystallized by the action of the nitrogenous liquid. The proportions used were 90 per cent. bone oil and 10 per cent. paraffin spirit, with lithium as the metal. The tube used was a coil-tube of Lowmoor iron, 4 inches in external, ½-inch internal diameter, and 24 inches long. Three grms. of lithium was employed, and the tube filled three parts of its length with the mixed liquids, a little lamp-black added, and welded up. It was heated 14 hours to a dull red-heat, and then bored open. A very high pressure was found to exist inside the tube, and as the material was at the other end of the tube it was removed by a long punch. It was found to be a mixture of carbon and lithium compounds, with some cyanides. Some of the carbon was very hard, but could be crushed by agate, and would not scratch it; but there was mixed with it (as with many of the other experiments) a few grains of silica. This was, perhaps, introduced in the welding, as a little silica had to be employed here, and a little may have been added with the lamp-black, which was never quite free from sand or other accidental impurity. The silica particles were easily removed by placing the substance on the stage of the microscope, and examining by polarized light, when all the particles which showed rotary power were removed.

The results obtained by the use of the two liquids being so much more satisfactory, further experiments were undertaken in this direction, and a series of four tubes filled with varying proportions. The

tubes had the dimensions $20'' \times 3\frac{3}{4}'' \times \frac{1}{2}''$ bore, and had 3 grms. of lithium introduced into each and then filled as follows:

No. I.	80 per cent.	bone oil,	20 per cent.	paraffin spirit	}	5 grms. of
" II.	40 "	"	60 "	"	}	lamp-black
" III.	20 "	"	80 "	"	}	added to
" IV.	10 "	"	90 "	"	}	each.

These were heated separately in the furnace, with the result that Nos. I and III burst, and Nos. II and IV withstood the pressure. No. II on being bored open gave off a great volume of gas, but on removing the contents nothing but lithium compounds and soft carbon was obtained. No. IV also evolved much gas, but the solid matter was very hard and contained some hard particles of carbon, but no diamond. It seemed therefore probable that some such proportion of ingredients might yield successful results, and another series of five, ranging from 30 per cent. to 10 per cent. of bone oil distillate, was prepared, and not one of them gave any results. One by one the tubes exploded, and the furnace had to be reconstructed at the fourth experiment. I thought I should either have to abandon the attempt or begin experiments of a very expensive nature, using large tubes and a large furnace, as 20-inch tubes of a greater diameter than 4 inches could not be closed when three parts filled—at least by welding. As some of them, however, seemed to stand, I determined to make some further trials with the apparatus I had at my disposal; so another tube, $20'' \times 4'' \times \frac{1}{2}''$ bore was filled, using 4 grms. of lithium and a mixture of bone oil, carefully rectified, 90 per cent., and paraffin spirit 10 per cent., using these proportions because I had never had any results with a high percentage of bone-oil, the tubes so filled having burst. The tube was closed with great difficulty, being three parts full of liquid, and then heated to a visible red-heat for fourteen hours, and allowed to cool slowly. On opening the tube a great volume of gas was given off, and only a little liquid remained. In the end of the tube which had been the upper end in the furnace, the tube lying obliquely, there was a hard smooth mass adhering to the sides of the tube, and entirely covering the bottom. As I had never obtained all the solids in one piece before, I wished to examine it, and so had the other end of the tube cut off, exposing the hard mass. It was quite black, and was removed with a chisel, and as it appeared to be composed principally of iron and lithium it was laid aside for analysis. I was pulverizing it in a mortar, when I felt that some parts of the

material were extremely hard—not resisting a blow, but hard otherwise. On looking closer, I saw that these were mostly transparent pieces imbedded in the hard matrix, and on triturating them I obtained some free from the black matter. They turned out to be crystalline carbon, exactly like diamond. I shall describe further on the analyses, etc., but will here go on with the account of my further experiments. Two tubes were filled in the same manner as the last, but one burst on heating, and the other had leaked so that there was no reaction. Two more tubes were prepared, but were spoiled on welding, and on cutting off the carbonized portion the remainder was too short to work. After much trouble three tubes were obtained, well closed, in which the three alkali metals were inclosed with liquid containing 20 per cent. bone oil and 80 per cent. paraffin. All three stood, and, on opening, only the potassium one had leaked to any extent. The results were not good, however, the sodium tube containing only soft scaly carbon, and the other two very little better. The reaction did not seem to have proceeded in the same manner in the lithium tube as before, as the mass was soft and friable. Still, lithium seemed to yield the best results, so it was adhered to in the further experiments. A list of disasters now awaited me. Eight tubes failed through bursting and leaking, and one of the explosions, when two were being heated together, destroyed a part of the furnace and injured one of my workmen. Besides this, two tubes were spoiled in welding. However, I had four experiments after this, all withstanding the pressure, and in one of these, with 10 per cent. bone oil and 90 per cent. paraffin spirit, a small quantity of diamond was found. The contents of this tube were different from the other successful one, being much looser and not in the same hard mass as the first. In another series of six experiments two were at first thought to have been successful, but I afterwards found that one of them was not so, the transparent matter being siliceous, but insoluble in cold hydrofluoric acid, although it dissolved on boiling. The uncertainty and great expense involved in using these forged coils of iron with tubes bored out of the solid induced me to again try steel, and Messrs. Cammell & Co. having prepared some tubes for me, I tried them, but with the same results—they exploded into fragments at a red-heat. And herein they are much more dangerous than coiled tubes, because the latter seldom fly into fragments, but just tear open a little. A further unforeseen danger in using steel tubes was discovered. One

which had stood the heating very well was being bored, and when the inner skin was cut so that the gas rushed out, the whole exploded, endangering the life of the workman who was boring, but as he was standing at the end of the tube and the pieces flew laterally he was not hurt. I have performed over eighty experiments, and have only obtained three results of a successful nature. The identification of the crystalline pieces as carbon was easy enough, but I have been anxious to find whether they are pure carbon or a compound with some other element, and to that end the following experiments were conducted.

A portion of the substance from the first successful experiment was weighed out after it had been freed from all foreign matter adhering to it, and placed in a very small platinum boat made of a strip of thin foil, the ends of which were wrapped round two stout platinum wires which were sealed into a wide glass tube. The carbon particles were transferred to this boat after being weighed, and the tube connected by india-rubber stoppers with an oxygen gasometer on the one side and a series of potash bulbs on the other. The oxygen was dried over solid caustic potash before entering the tube, and again after leaving the potash bulbs. The carbon (14 mgrms.) having been weighed out, the potash bulbs were weighed, and a current of oxygen passed through the apparatus, and the platinum wires connected with a battery strong enough to heat the foil to a bright red-heat. After a few minutes the oxygen was stopped and the bulbs weighed, when it was found that they had gained 1 mgrm. On repeating this operation no gain was found, the moisture having been entirely driven off by the first treatment. The carbon was now placed in the boat and a slow current of oxygen started, then the bulbs connected and the current made to pass through the platinum until all the diamond had been burnt, when the current was stopped and the oxygen allowed to pass for fifteen minutes more, when the bulbs were detached and weighed. They were then reconnected and the gas passed for another ten minutes to find whether all the carbonic acid had been expelled and reweighed. They weighed 0·2 mgrm. less than before. The numbers were as follows:

Potash bulbs before combustion,	43·8308	
" " after "	43·8776	
		·0468
Drying tube before combustion,	26·4294	
" " after "	26·4328	
		·0034
		·0502

This gives a composition of 97·85 per cent. of carbon, which is a pretty fair approximation to pure carbon. However, to determine whether or not this was not the case, some further experiments were tried. A small quantity of the carbon was placed on the platinum boat and burnt in oxygen without any of the gas being allowed to pass out of the apparatus, and the mixed gases so obtained transferred to a eudiometer, and the carbonic acid and oxygen absorbed. It was then found that a residue amounting to about 3 per cent. by volume of the carbonic acid was left unabsorbed by alkaline pyrogallate solution. This proved to be nitrogen. A blank experiment was done, but it gave only a minute bubble of nitrogen. Another experiment was performed with the following results:

Total volume, ...	183·7		
After absorption of CO_2, .	148·5	CO_2 =	35·2
After " " O, . .	1·1	O	147·4
		N	1·1

This plainly shows that nitrogen was present from some cause or another, and as every precaution was taken in transferring the gas from one vessel to another, and as the blank experiment showed nothing, I am inclined to believe that the carbon, or at least some portions of it, contained nitrogen chemically combined. The numbers above given are degrees on the eudiometer tube, and are not more than one-third of a cubic centimetre each. Their exact value was of no consequence in the experiment, and the tube was only calibrated by comparing one part with another, and not with an absolute measure.

From the fact that no diamond was found when nitrogen compounds were absent, and from the fact that the mixed product (for only a portion of the 14 ngrms. was clear diamond) contains nitrogen, I am inclined to believe that it is by the decomposition of a nitrogenous body, and not the hydrocarbon, that the diamond is formed in this reaction. The experiments are, however, too few, and the evidence too vague, to draw any conclusions, as there are even very few negative experiments from which anything can be learned, most of the results being lost by explosion. I intend, when my other work—which I had aside for the diamond experiments—is finished, to begin a series of experiments on the decompositions of carbon compounds by metals, to find whether a more easily controlled reaction may not be discovered.

THE "GILLOTYPE" ENGRAVING PROCESS.

Extract from a notice in *Engineering*, of the recent Exhibition of Printing Machinery in London.

The so-called Gillotype engraving process is shown in its various stages by Messrs. A. S. Cattell & Co., of London, and since this process is an interesting one, and largely employed for the production of plates suitable for surface printing, it calls for some notice. A reversed drawing of the object to be engraved is first made on lithographic stone in the ordinary manner. From this drawing an impression is taken on a specially prepared transfer paper, just in the same way as an ordinary proof would be pulled from it, and the transfer is placed face downwards upon a highly-polished and perfectly flat zinc plate and exposed to considerable pressure, by which means a reverted picture is obtained on the plate, and a roller charged with a greasy ink is passed over it, the ink adhering to the lines on the plate, but to no other part of it. The plate is then placed in a rocking cradle containing a bath of highly diluted nitric acid, and the cradle is kept in constant gentle oscillation. The acid attacks all those parts of the metal not protected by the ink, and by eating it away produces a raised picture after some time of exposure; the rocking motion being necessary to remove the gas bubbles which form by the action of the acid on the zinc. It will be evident that without precaution being taken, the acid would very soon attack the sides of the lines thus raised and undermine them; to avoid this the plate is frequently taken out of the bath and rolled with the inked roller, after which it is slightly warmed to cause the ink to run down the sides of the raised lines, and so protect them. By these alternate operations of inking and eating away with acid the necessary depth for printing is gradually obtained, but the process is a slow one, requiring from three to eight hours, according to the nature of the work, and this again governs the strength of the acid used. Very fine work requires weak acid, and a long time for engraving, while coarser engraving can be bitten out more rapidly. The plates when completely engraved require some finishing and handwork, such as squaring up, trimming the edges, etc., and they are then mounted upon wood blocks to suit the height of the type with which they are

to be printed. The thickness of the zinc plates used is from $\frac{1}{16}$ to $\frac{1}{4}$ inch.

The same process of zinc engraving as above described can also be employed for the production of any subject, a picture of which is produced on the zinc in other ways than by lithography. Thus transfers from a steel or copper engraved plate or a photograph can be produced, the latter on a specially prepared zinc surface, or a sketch may be made on the zinc direct with lithographic ink or chalk.

Simple as this process appears, it requires considerable skill and care on the part of the operators to produce really good results, but some excellent specimens of blocks, as well as prints from the same, may be seen at the show, or at any time in the columns of this journal, our line engravings being prepared exclusively in this manner. The applications of this process are very various and widespread, and the advantages it possesses over line wood engraving are manifest. The simplest sketches, or the most complicated drawings covered with dimensions and writing, are produced with almost equal facility; fac-similes of ancient inscriptions, manuscripts, etc., can be photographed direct upon zinc, and require practically no hand labor, so that absolute accuracy is obtained. These are only a few applications, but are sufficient to show that the process is superior in many respects to the much older art of wood engraving, although it must always remain inferior to it where effects of color are required.

Volatile Power of Liquids. Pictet gives a general equation, drawn directly from the mechanical theory of heat, which embraces all Regnault's equations of interpolation for all known volatile liquids; in other words, it gives the maximum tension of any given vapor at any given temperature. Let λ be the latent heat of volatilization at a temperature t; c the specific heat of the liquid; k the specific heat of the vapors; P the maximum tension of the vapors at temperature t; δ density of the vapors, varying according to the law of the co-volumes; $f\left(\frac{P'}{P}\right)$ a specific integral deduced from the work done, in accordance with Mariotte's law. Then

$$f\left(\frac{P'}{P}\right) = \frac{[\lambda' + (c - k)(t' - t)]\,431 \times 274 \times 1{\cdot}293\,\delta\,(P - q)}{10333\,(274 + t')(274 + t)}$$

—*Comptes Rendus.*

LIGHTING ROOMS.

M. Javal, in a paper on public and private lighting, considered from the aspect of ocular hygiene (*Revue Scientifique*, Oct. 18, 1879, p. 361), treats of artificial lighting. He says, that a chandelier, carrying a million of wax lights, would not give an amount of light equal to sunlight. Even in a room, lit up in an unusually brilliant manner, the pupils are much more dilated than in full daylight; and this dilation explains the fatigue to the eyes produced by artificial light. Therefore, there is never too much, in fact never enough, artificial light, and prejudices, without any just foundation, are prevalent on this point. M. Javal recommends to persons suffering from certain optic defects, and who cannot work in the evening, two large lamps, which would obviate the fatigue of reading. Artificial light, also, excepting the electric and magnesium lights, contain much fewer chemical rays than daylight. All artificial spectra are very dull on the most refracted side; the chemical rays, the violets and the blues, there show a very low intensity. M. Bouchardat (*Revue Scientifique*, August 16, 1879, p. 148) has shown the dangers of violet and deep violet rays, on the authority of M. Regnauld's important work on the fluorescence of the media of the eye. The conclusion to be derived is that the flame light being poorer in chemical rays than sunlight, should be preferred by workers. In fact, M. Javal quotes the instance of a member of the Institute, whose fatigued vision would scarcely tolerate daylight, and who shut his shutters, and lighted his lamp, in order to work. M. Javal recommended him rather to work in daylight, with yellow spectacles, to destroy the chemical rays. Artificial light, on the other hand, considerably dilates the pupil, and renders the chromatism of the eye more sensitive, which is the reason that the light of day is to be preferred. The electric light is injurious, in a certain point of view; it contains a large quantity of chemical rays, which it would be easy to neutralize by giving a yellow tint to the globes. Nevertheless, neither the public, nor the experts, have complained, up to the present time, of the electric light; inconveniences only arise when the eyes are fixed for too long a time on a too powerful electric light. It is therefore advisable not to look too long at electric lights, and when this becomes a habit, the opacity of the globes now in use can be

diminished. In fine, all our systems of artificial light are insufficient: there is, then, no necessity to fear excess of light, since, on the contrary, artificial light is less penetrating than daylight. Gas, therefore, does not destroy the eyesight, it is the wavering and flickering of the flame, when there is neither globe nor chimney, which fatigues the sight; gaslight, with a burner protected by a globe, is excellent for it. M. Javal may well, then, say, with dying Göthe —"Light, more Light!" —*Sanitary Record.*

A NEW DEVELOPER IN PHOTOGRAPHY.

By Capt. W. de W. Abney, R.E., F.R.S., &c.

Some two years ago I began a series of experiments on developing agents, with a view of finding some one which would only act on the silver bromide which had been acted upon by light, and not on silver bromide as well. Now every one is aware that the ordinary alkaline development (except by a *tour de force*) acts upon silver bromide unless a restrainer or retarder such as gelatine or soluble bromide is at hand during the development. Except in the case of albumen beer plates in the form which I originally introduced, no collodion film, as far as I am aware, could be treated with pyrogallic acid and neat ammonia without a hopeless fog ensuing. In this case the albumen acted very much like gelatine does in the gelatine-bromide plates, and this process is therefore no exception to the rule. The most crucial test for a developer is to apply it to a plate coated with ordinary washed collodio-bromide emulsion, the film having no preservatives. There are several organic substances which can be applied as preservatives, and which, when ammonia is applied, will cause a faint image to be developed; but intensity is always wanting. It would scarcely interest my readers to give the theoretical reasonings which led me to try a substance which is but little known, viz., hydro-kinone. It is sufficient to say that as a developing agent it is very perfect, and can be used in a collodion emulsion film without the slightest trace of restrainer or retarder; in other words, it requires no soluble bromide with it.

Hydro-kinone is a derivative from kinone, and, on the addition of certain metallic compounds to it, acts as a reducing agent. It is solu-

ble in alcohol, and in water to a large extent. The following experiments are worth a trial. Dissolve one grain in two drachms of water, and expose a collodio-bromide plate for half the time necessary with the ordinary alkaline developer, and apply this quantity of liquid with one drop of strong ammonia. The image will appear quietly, and show all detail, but on fixing will be rather too feeble; it will take silver intensification, however, perfectly. Double the quantity of hydro-kinone, and again develop a plate, and it will be found that the intensity is of a medium character, whilst by trebling it, it will be found that proper density is secured. With gelatine plates the same experiment may be repeated, a less quantity being apparently requisite to give proper printing density, than with collodion films. On fixing the plates they will be found perfectly free from any veil caused by a reduction where no reduction should be, and they will give brilliant prints.

It may be asked if the hydro-kinone has any advantage over the ordinary alkaline developer. I am inclined to think it has—in that the faintest trace of the action of light is made apparent, and is not destroyed by the soluble bromide. This should be a decided gain, and on testing it against ferrous oxalate (without bromide) in gelatine plates, it seems as if this were borne out. With collodion plates it has a decided advantage, and it may be worth a trial. A curious experiment is to prepare a collodion plate, wash it, and pour over it a solution of hydro-kinone and ammonia, and then expose in the camera; it will be found that development commences during the exposure; whereas such an attempt made with ordinary alkaline or ferrous oxalate developer would prove a failure. The great objection to the use of this compound is its price; it is expensive, but doubtless any demand for it would quickly reduce it to nearly the same price as pyrogallic acid. It is at present more a chemical curiosity than of any commercial use, but if it should prove to be a good developer, it would speedily find its way into the price list of manufacturing chemists at a more moderate rate than that at which it is now shown.—*Photographic News.*

Roof Varnish.—A varnish for roofs has been recently patented in Germany which is composed of 35 parts of clay slate, 30 parts mica slate and 35 parts rosin, all finely powdered and heated with 50 parts of tar.—*Bay. Ind. und Gewerbeblatt.* C.

MEAT BREAD.

M. Scheurer-Kestner has discovered the remarkable fact that the fermentation of bread causes the complete digestion of meat. He found that a beef steak cut into four pieces, and mixed with flour and yeast, disappeared entirely during the process of fermentation, its nutritive principles becoming incorporated with the bread. The meat would also appear capable of preservation for an indefinite period in its new state, for loaves of meat bread, made in 1873 have been submitted to the French Academy of Science, when not a trace of worms or mouldiness was observable. At the beginning of his experiments, M. Scheurer-Kestner used raw meat, three parts of which, finely minced, he mixed with five parts of flour and the same quantity of yeast. Sufficient water was added to make the dough, which in due time began to ferment. After two or three hours, the meat had disappeared, and the bread was baked in the ordinary manner. Thus prepared, the meat bread had a disagreeable, sour taste, which was avoided by cooking the meat for an hour with sufficient water to afterwards moisten the flour. The meat must be carefully deprived of fat, and only have sufficient salt to bring out the flavor, as salt, by absorbing moisture from the air, would tend to spoil the bread. A part of the beef may be replaced with advantage by salt lard, which is found to improve the flavor. The proportion of meat to flour should not exceed one half, so as to insure complete digestion. Bread made with a suitable proportion of veal is said to furnish excellent soup for the sick and wounded.—*Sanitary Record.*

Crystalline Form of Magnesium.—Des Cloizeaux has examined some beautiful crystals of magnesium, which were presented to the French Academy by M. Dumas. The crystals were obtained by sublimation and are of a white color, with the brilliancy of silver. Their faces are often curved and the edges blunt; the usual form is that of a regular hexagonal prism, terminated by a base which is a little less brilliant than the lateral faces. The edges of the base are often replaced by an annular truncation, the combination of which with the faces of the prism recalls that of tellurium crystals. The culminating angle is more acute than in the other rhombohedral metals, arsenic, tellurium, antimony and bismuth. The crystals are very malleable and sectile, but without visible cleavage.—*Compt. Rend.* C.

Earthen Filtering Plates.—G. W. Reye & Sons, of Hamburg, make filtering plates from a mixture of one part of gypsum with three parts of imperial earth in water. They can be purified after using by washing or burning. When impregnated with carbolic acid they also become useful as disinfectants.—*Dingler's Journal.* C.

Electric Sun.—Lontin has been exhibiting in the building of the Industrial Exhibition in the Champs Elysées, Paris, a circular electric light, formed by four voltaic arches. He uses four carbons placed radially, the two which are in the same diameter being connected with the same pole, so that an arch extends from each of the carbons to each of its neighbors. These four arches unite to form a complete circle and produce a light of extraordinary brilliancy.—*Dingl. Jour.* C.

Dissociation of Metalloids.—Pictet proposes a plan which he thinks might effect the dissociation of metalloids, but which is too costly for him to undertake at his own expense. It consists of a parabolic mirror, with a section normal to the sun's rays which should have at least 35 metres (41·86 sq. yards) of surface. He estimates that this would give a heat equivalent to 1000 calories (2200 thermal units) per minute, and that such a heat would probably be sufficient to decompose any of the metalloids which are really compound bodies.—*Les Mondes.* C.

An Intensified Electro-Magnet.—Dr. Stone recently exhibited before the Physical Society a very interesting electro-magnet of novel construction, and based on a principle which will probably be applied with advantage in the construction of electro-magnets for dynamo-electric machines and telegraphic apparatus. It is known that electro-magnets enclosed in jackets of soft iron are far more powerful than when the copper coil of wire is unenclosed. In fact, the iron jacket, like the second armature or diaphragm in M. Ader's form of Bell telephone recently described by us, has the effect of exalting the magnetic power of the poles. Dr. Stone does not employ a soft iron jacket, but instead of using copper wire to wind the bobbins he uses best charcoal annealed iron wire about $\frac{1}{5}$ in. in diameter, Four wires are wound on in parallel circuits, and the current is split up among them in "multiple arc." They are insulated from each other by paraffine wax. By this felicitous arrangement the lifting power of Dr. Stone's large magnet is, with a battery of four or five Bunsen cells, increased fourfold.—*Engineering.*

COMMUNICATIONS.

U. S. NAVAL OBSERVATORY,
Washington, D. C., June 15, 1880.

Committee on Publication of the Franklin Institute Journal:

GENTLEMEN:—Some months ago I had occasion to investigate the strength of a particular class of gearing, and now it seems desirable to extend the investigation to all kinds of gearing. The numerical values of the coefficients in my formula can only be determined from wheels in actual use, which are known to be working up to their full capacity. The data required are:

1. The material composing the wheel.
2. Its diameter at the pitch line.
3. The width of its face.
4. The number of its teeth.
5. Its pitch.
6. The number of revolutions it makes per minute.
7. The number of horse-power transmitted by it; or, the pressure in pounds at its pitch line.
8. A statement of the kind of machinery it drives.

These data will be of no value unless it is known that the wheel is working up to its full capacity, and in every case the reasons for supposing that it is doing so should be stated.

The method of determining the pressure at the pitch line should also be stated. If the wheel transmits the full power of an engine, its actual, not its nominal, horse-power should be given. In such cases the power should be determined from indicator diagrams, if possible. When that cannot be done the following particulars should be specified concerning the engine:

1. Condensing or non-condensing.
2. Diameter of piston.
3. Length of stroke.
4. Number of revolutions per minute.
5. Pressure of steam.
6. Point at which the steam is cut off.

May I appeal to your readers to furnish me such information? If

enough is forthcoming to yield a satisfactory result, I will be very happy, with your permission, to publish my investigation in your Journal; and full credit will be given to all who have furnished data.

Yours, very respectfully,

WM. HARKNESS.

WOOD PRESERVATION.

To Engineers, Architects, Preservers of Wood, Chemists, and Others:

The undersigned, a Committee of the American Society of Civil Engineers appointed to report upon the Preservation of Timber, earnestly solicit information concerning past experience in the impregnation and preservation of that material.

Particulars of failures in this country, and if possible the reasons therefor, are specially desired. Also, information on the following points, in each of the processes, which may have been used:

1. Kind of timber operated on—green or dry—age, dimensions, etc.
2. Preserving ingredients injected.
3. Quantity injected per cubic foot or tie.
4. Mode of application, process, time employed, degree of heat, pressure, vacuum, etc.
5. Subsequent use and exposure of timber (bridges, buildings, or track).
6. Result of preparation and comparison with life of unprepared timber.

This special and any general information on the subject is respectfully solicited.

Replies can be mailed to the chairman of the committee.

B. M. HARROD, *Chairman*,
122 Common Street, New Orleans, La.
G. Bouscaren, 82 West Third St., Cincinnati, O.
E. R. Andrews, 10 Warren St., New York City, N. Y.
E. W. Bowditch, 60 Devonshire St., Boston, Mass.
Col. Geo. H. Mendell, U. S. Engineers, San Francisco, Cal.
J. W. Putnam, P. O. Box 2734, New Orleans, La.

Committee.

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EXPERIMENTS ON THE COMPRESSION OF AIR BY THE DIRECT ACTION OF WATER.

By J. P. FRIZELL, C.E.

Some ten years ago, the writer's attention was called to the compressing of air for mechanical purposes by causing it, in the form of minute bubbles, to be carried downward in a current of water and lodged in a receiver by changing the direction of the current from vertical to horizontal.

Such a method appeared to promise important advantages over existing methods of utilizing water power, putting it in a form to be transmitted to distant points and allowing the location of mills and factories to be chosen without reference to the requirements of water wheels.

The application of this method on a scale corresponding to a high degree of efficiency would involve a large expense and its entirely novel and experimental character seemed to render hopeless any attempt to bring it to the notice of capitalists. Nothing was therefore done in the way of its development beyond theoretical researches and some crude and simple experiments till within a couple of years.

Public attention was first called to the subject in a paper published in the JOURNAL OF THE FRANKLIN INSTITUTE for September, 1877, in which the theory of the method was set forth and its probable

advantages pointed out. This had the effect to excite the interest of a prominent New England manufacturer, Gen. J. C. Palfrey of Boston, at whose expense the experiments to be detailed have been mainly conducted.

It was well understood that a practically satisfactory efficiency could not be obtained from a model. With a low velocity, narrow passages and small head, the resistances bear a large proportion to the motive power, and may even absorb it altogether. Theoretical considerations indicate that the efficiency increases with these several elements, till it may in certain conditions reach as high as 80 per cent. or even higher.

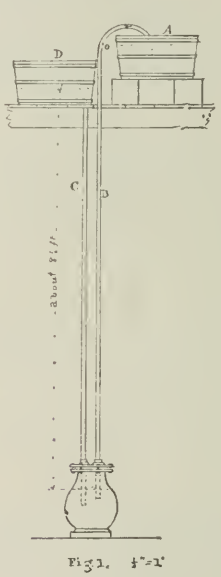


Fig. 1. 1"=1'

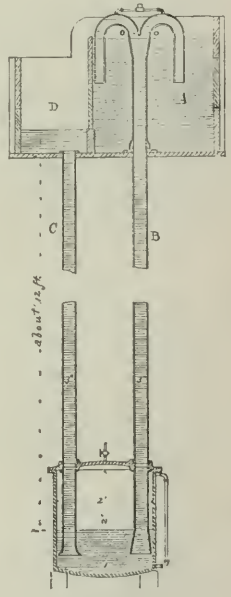


Fig. 2. ½"=1'

The apparatus first tried is represented in Fig. 1. Two glass tubes, *B* and *C*, were passed through the cover of a strong glass vessel, the fittings being, as near as possible, air-tight. The tube *B* terminated at the upper end in a siphon, and dipped into a tub, *A*, kept nearly full of water. The tube *C* opened into another tub, *D*. The tube *B* had a small orifice at the summit, closed by a flap valve, for exhausting the air. There was another minute orifice at *o*. The two tubs being filled with water as indicated by the dotted lines, the water, of course, filling the receiver and rising in the tube *B* to the level of the

surface in the tub *D*, the siphon was set in action by placing the finger over the orifice *o*, and exhausting the air by applying the mouth to the summit orifice, then closing the latter. The flow was kept up by dipping the water from the lower to the higher tub. The pressure within the tube at the point *o* being a little less than that of the atmosphere, the air enters there and is carried downward by the current and lodged in the receiver.

This device worked very well as an illustration of the method.

The quantity of air collected in the receiver was very small. No attempt at an exact estimate of the useful effect was made. It was very slight, probably not over 5 per cent., certainly not over 10 per cent. of the power expended. The diameter of the tubes was 1¼ inches. The air accumulated under a pressure of 8 or 9 feet of water. The head or difference of level between the two tubs was 8 to 12 inches.

No difficulties not previously foreseen being developed by this experiment, it was decided to try the method on a larger scale. For this purpose the apparatus represented in Fig. 2 was constructed. The receiver was of cast iron, circular, 2 feet diameter, 2 feet high. The pipes *B* and *C* were of iron 3 inches diameter inside. The water was supplied from a wooden tank in two compartments, *A*, *D*, the flow being maintained by pumping the water from the lower to the higher level, with a small centrifugal pump driven by steam, which does not appear in the cut. The pipe *B* terminated, as before, in a siphon, or rather this time, in two siphons, provided at their summits with connections for an air pump to set them in action. The air was admitted, as before, through minute orifices, *o*, *o*, just above the surface of the water in the chamber *A*. A glass gauge on the receiver showed the quantity of air contained in it. The pressure of the air is measured by a column of water equal to the height of the surface in the chamber *D* above that in the receiver.

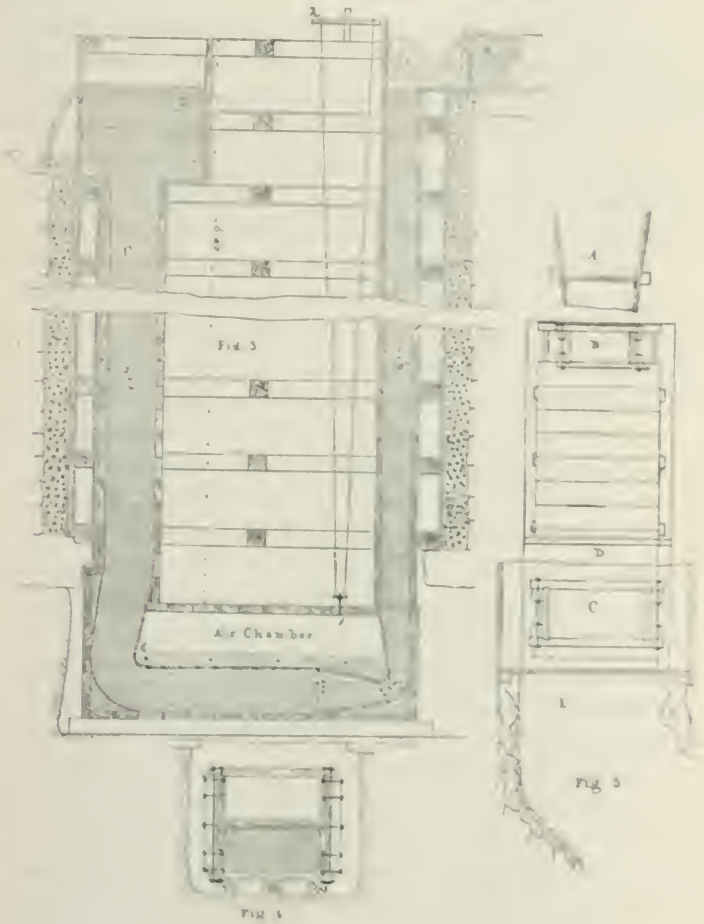
This apparatus was exhibited at the fair of the charitable Mechanic Association in Boston, in 1878. It was afterwards set up in the laboratory of mechanical engineering at the Massachusetts Institute of Technology, and became the subject of critical experiments by Professor Whitaker and members of his class. The quantity of water was inferred from the velocity of the pump. The velocity could also be observed, but not very closely, in the descending shaft, which, near the bottom, was of glass. From the best data attainable, Mr. Whitaker computed the efficiency at 26½ per cent: that is, the power repre-

sented by the air after compression is but 26½ per cent. of that represented by the water employed in compressing it. The head in this experiment was about 25 inches. This result, though at once accepted by the unthinking as a failure of the method, was so entirely in accordance with the true theory of the subject that it strengthened our confidence and induced us to make a trial upon a larger scale. In the meantime I had been called by business to St. Paul, Minn.

The application of this method on any greater than the laboratory scale requires conditions very rarely met with, viz.: a deep pit, free from water, in the immediate vicinity of a small waterfall. These conditions happened to be presented at the Falls of St. Anthony, on the Mississippi river a few miles above St. Paul. A vertical shaft was sunk by the United States Engineer Department, several years since, in the work for the preservation of the falls, and had never been refilled. It was about 36 feet deep and was drained by a pipe opening into the river below the falls. Its clear dimensions, inside the timbering, were about 6 × 14 feet. It occupied a narrow island between two mill ponds, one of which was maintained some 8 or 10 feet higher than the other.

Permission to occupy this shaft for the purpose in question was readily given by the officer in charge of works in this district, C. J. Allen, Captain of Engineers, and Dr. S. H. Chute, one of the managers of the St. Anthony Water Power Company, kindly gave permission to use the water and make the necessary excavation for races. The apparatus, except the raceways, is shown in Figs. 3, 4 and 5. Figure 3 is a vertical longitudinal section; Fig. 4 a cross section through the air chamber, and Fig. 5 a plan. The apparatus consists of a strong wooden tank at the bottom of the pit, with two vertical shafts or channels rising to the surface of the ground. The shaft for the descent of the water, in which a considerable velocity is required, is 15 × 30 inches. The ascending shaft, whose function is to return the water to the surface with as little loss of head as possible, is 24 × 48 inches. The upper part of the tank between the vertical passages is occupied by the air chamber which is lined with zinc and is furnished with a cock, *f*, operated from above, as shown, for the escape of air. The air chamber is separated from the passage below it by a partition of boards laid with openings which allow the air to pass freely into the chamber. It will be noticed that the descending shaft, at the bottom, is contracted strongly in the plane of the section, though it expands

somewhat in the direction at right angles thereto. It was apprehended that the air might tend to aggregate in masses as soon as it departed from the perpendicular direction. This disposition was intended to quicken the velocity a little at that point and make the change of



direction as abrupt as possible. This involved some loss of head, more than was necessary, as I am inclined to think. The flaring of the passage, after assuming the horizontal direction, was designed to utilize the *vis viva* lost by the water in passing from the higher to the lower velocity. The dimensions of the pit did not admit of so long a horizontal passage as was desirable. A glass gauge was first applied

to the air chamber, as in the arrangement already described. The drenching to which it would subject an observer, however, decided me to abandon this, and adopt an arrangement bringing all the essential facts of the process under the eye of a single observer above ground. An opening, *g*, was made in the side of the air chamber just 21 inches below the top, opening into the ascending shaft. The filling of the air chamber to the depth of 21 inches was announced by the appearance of large bubbles in the chamber *D*, followed in a few seconds by a violent commotion therein. By raising the lever, *h*, the air accumulated in the chamber was discharged, the cessation of the loud hissing indicating the complete emptying of the chamber.

The water was discharged from the chamber *D* over a weir 5·56 feet long. A gauge in this chamber indicated the depth on the weir, and, in connection with another in the chamber *A*, the fall. The fall, it is hardly necessary to observe, is the height of the surface in the chamber *A* above that in the chamber *D*. The pressure of the air is determined by the height in the latter above that in the air chamber. The leakage, which was considerable, was readily determined by observing the rate at which the water fell in the chamber *D* after shutting off its admission. The fall was varied by adjustable weir plank. At each change of weir plank, the reading of the gauge was taken when the water was exactly at the crest of the weir. This reading subtracted from that taken during the flow of the water gave the depth on the weir. No microscopic nicety, but only substantial accuracy was attempted in any of these observations. The tank and the lower part of the ascending shaft were of four inch pine plank. The rest of three and two inch plank, all confined by an immense number of screw and lag bolts with large cast iron washers. The timber was put in quite dry and joints paid with white lead and oil in the expectation that the swelling would make all tight. This expectation was not fully realized, the great pressure starting some of the joints and causing considerable leakage, amounting in some cases to nearly half a cubic foot per second. This was, of course, added to the quantity passing the weir.

As originally constructed, the upper part of the shaft was provided with a siphon, as in previous arrangements. Meeting with great difficulty in exhausting the air, I decided to take it out and rebuild it on a different plan, but in the meantime took occasion to make an experiment which I had contemplated from the first, viz., to ascertain whether the introduction of the air could not be equally well accomplished by

giving the water a slight fall at its entrance. The readiness with which water in violent agitation breaks into foam is familiar to all, as well as the fact that foam is nothing more than water impregnated with minute air bubbles.

The method adopted was the one indicated in the sketch, viz., allowing the water to fall into the descending shaft over a barrier of stop-plank. The complete success of the experiment made it apparent that the siphon might henceforth be dismissed from the method, although it would undoubtedly have some advantage as regards efficiency, especially with a low head.

In the theory of the subject formerly presented I assumed 12 inches per second as the velocity with which bubbles of air rise in still water. This was founded on experiments with bubbles formed by air escaping through orifices. In the process above described the air appears to be broken up into finer bubbles, which do not rise so fast. I found that a velocity of 0·75 ft. per sec. in the descending shaft brought an appreciable quantity of air into the chamber; 0·86 ft. brought it in freely.

The mode of conducting experiments on compression was as follows: The water being turned on and flowing in full volume over the weir, the air chamber being empty, the escape valve was closed by the lever, *h*, and at the same instant a stop watch was started. The gauges in *A* and *D* were observed and recorded; then the eye was fixed on the surface in *D*. On the appearance of large air bubbles here, the watch was stopped. It must be observed that when the velocity in the descending shaft much exceeded three feet per second large quantities of air were carried past the air chamber, and rose in the ascending shaft. There was no danger, however, of confounding these bubbles with those announcing the filling of the air chamber, the latter being larger and immediately followed by a great commotion in the basin *D*.

The passage of air past the air chamber disposes of one difficulty that has been predicted of this method, viz., that the air would tend to aggregate in large masses. No tendency of this kind was observable in the air coming up the ascending shaft, though it had traversed a distance of over 70 feet. It reached the surface in fine bubbles, very nearly uniform in size.

The capacity of the air chamber, filled to a depth of 21 inches, was 71·19 cubic feet. The following is an example of the computations:

Take experiment No. 1. Fall, 4·07 feet; depth on weir, 0·63 ft.;

quantity of water, $1{\cdot}665 \times (5{\cdot}56 - 0{\cdot}2 \times 0{\cdot}63) +$ (leakage) $0{\cdot}41 =$ 9·45 cubic feet per second.

Pressure of air, ... 27·58 ft. water.

Power of 1 cub. ft. air—Admission, $27{\cdot}58 \times 62{\cdot}3 = 1780{\cdot}5$ ft. lbs.

" " " —Expansion $= \frac{1780{\cdot}5}{2} \times \frac{27{\cdot}58}{34} = 747{\cdot}8$ " "

Total, . . 2528·3 " "

Time, from closing of escape valve to appearance of bubbles, 2 m. 48 s.

Velocity of water in ascending shaft, $\frac{9{\cdot}45}{8} = 1{\cdot}18$ do. of air, 2·18 ft. per second.

Time of rising of air bubbles, $\frac{27{\cdot}58}{2{\cdot}18} = 13$ seconds.

Time of filling of air chamber = 2 m. 48 s. — 13 s. = 2 m. 35 s. = 2·583 minutes.

Quantity of air per minute $= \frac{71{\cdot}19}{2{\cdot}583} = 27{\cdot}60$ cubic feet.

Power of air per minute $= 2528{\cdot}3 \times 27{\cdot}60 = 69781{\cdot}$ ft. lbs.

" " water " $= 4{\cdot}07 \times 9{\cdot}45 \times 60 \times 62{\cdot}3 = 143780$ ft. lbs.

Percentage of useful effect $= \frac{69781}{143780} = 48{\cdot}5$ per cent.

No account was taken of the leakage of air, which was slight. The assumption that the mean pressure during expansion is half the initial pressure rather over-estimates the power of the air. On the other hand, taking an atmosphere at 34 feet water (its value at the sea level) leads to a greater error in the opposite direction. The bottom of the pit is about 750 feet above the sea level.

A large number of experiments were made before discovering the most advantageous conditions of working. Table I contains all the experiments covered by the dates therein given.

The best efficiency is 52 per cent., being about double the best result obtained with the apparatus, Fig. 2. This percentage would, of course, be entirely unsatisfactory in a practical motor; but an air-compressing system on a practical scale would exceed this model, in dimensions, in greater ratio than this exceeds the apparatus represented in Fig. 2. The object of these experiments is to ascertain what could be expected from such a system. Let us first see how these results accord with the theory of the subject.

Table I.

Results of Experiments in Compressing Air by causing it to mix with a Descending Current of Water.

No. of expt.	Date—1880	Head.—Feet.	Pressure on air in chamber in feet of water	Quantity of water—cub. feet per sec.	Quantity of air carried into chamber—cub. feet per minute	Power due to one cub. foot of air.	Total power of water.	Total power of water and air.	Percentage of useful effect.	Velocity in the descending shaft—feet per sec.
1	May 30	4·07	28·58	9·45	27·60	2528·3	69781	143780	48·5	3·02
2	" "	3·24	29·43	9·89	18·59	2627·1	48843	119780	40·8	3·16
3	" "	2·62	30·08	9·45	14·47	2703·2	39115	92540	42·3	3·02
4	" 31	2·54	29·91	5·92	8·53	2683	22877	56207	40·4	1·89
5	" "	0·98	.....	14·03	0·00	.....	.....	.....	.....	4·49
6	" "	4·82	27·68	10·34	31·40	2426·3	76193	186207	40·9	3·31
7	" "	4·70	27·75	11·89	38·07	2434	92668	208580	44·3	3·80
8	" "	4·77	27·75	11·80	35·95	2434·	87522	212000	41·3	3·80
9	" "	4·81	27·72	11·22	42·12	2430·7	102391	201733	50·7	3·59
10	" "	4·87	27·68	10·34	36·89	2427·2	89529	188230	47·6	3·31
11	" "	4·94	27·58	8·23	27·31	2415·2	65951	151973	43·4	2·68
12	June 2	4·78	27·64	9·46	34·90	2422	84519	169040	50·0	3·03
13	" "	4·79	27·64	9·46	36·41	2422	88200	169381	52·1	3·03
14	" "	5·01	27·47	6·10	21·42	2402·7	51476	114237	45·0	1·95
15	" "	5·02	27·46	5·92	21·44	2401·9	51503	111090	46·4	1·89

The losses of power, or the losses of head, which are the same thing, the head being taken to represent the power in any given experiment, are of three kinds: First, the loss at the entrance, or the fall required to impregnate the air with bubbles. This did not admit of very close measurement, but, as near as could be estimated, did not differ materially from one foot in all the experiments. Second, the resistances to movement. In experiment No. 5, with no air passing, a velocity of 4·49 feet per second in the descending shaft corresponds to a head of 0·98 feet wholly absorbed in resistances to movement. This gives the means of finding the resistance to movement for any other velocity, such resistance being represented by a head which is proportional to the square of the velocity. Third, a certain loss is occasioned by the fact that the air does not move downward with the same velocity as the water. The air bubbles, as I find, would rise in still water at the rate of 0·75 foot per second. When the water, therefore, is moving downward at the rate of 3 feet per second the air goes only 2·25. There is, then, a loss of power of $\frac{0{\cdot}75}{3{\cdot}00} = 25$ per cent. of the head

employed in compressing the air. Let us now apply these principles to computing the head in experiment 1.

Head lost at entrance, ... 1·000 feet.

" " in resistance to movement $= 0{\cdot}98 \left(\frac{3{\cdot}02}{4{\cdot}49}\right)^2 = 0{\cdot}443$ "

" " slip $= (4{\cdot}07 - 1{\cdot}443) \times \frac{0{\cdot}75}{3{\cdot}02}$ . . . $= 0{\cdot}653$ "

" expended usefully $= 4{\cdot}07 \times 48{\cdot}5$. $= 1{\cdot}974$ "

Total, ... 4·070 "

TABLE II.

Expt.	Head.		Expt.	Head.	
No.	Observed.	Computed.	No.	Observed.	Computed.
1	4·07	4·07	9	4·81	4·73
2	3·24	3·22	10	4·87	4·61
3	2·62	2·84	11	4·94	4·51
4	2·54	2·74	12	4·78	4·66
6	4·82	4·25	13	4·79	4·77
7	4·70	4·38	14	5·01	4·92
8	4·77	4·28	15	5·02	5·03

Table II contains the results of this calculation applied to all the experiments. The computed head falls short of the observed head in the experiments with velocities exceeding 3 feet per second, as was to be expected, since in these cases large quantities of air were carried past the chamber, involving resistances not taken account of in the computation. Moreover, in these cases, air counting as water, the tendency is to over-estimate the quantity passing the weir. One thing is especially to be noted. In the experiments giving the best results the agreement is quite satisfactory. We may, therefore, I apprehend, apply this method, with a good degree of confidence, to a system of practical size, understanding always that it is working to its best advantage.

For a system of practical size, we may fix the following dimensions: Descending shaft, 10 feet diameter, making the mean radius six times that of the model. Ascending shaft in same proportion. Depth, 120 feet, corresponding to a pressure of about 50 pounds per square inch, making the journeys of the water about four times that in experiment 5. Fall, 15 feet. Velocity in descending shaft, 6 feet per second. It would not be advisable to make such a system an exact copy of the model which, owing to the limited space, could not have the form best calculated to avoid loss of head.

The loss of head in experiment 5 was 0·98 foot, with a velocity of 4·49 feet per second.

The loss in the straight passages, by the best formulas, could not have exceeded . . . . . 0·200 foot.

The loss due to bends, chiefly the bend at the bottom of the descending shaft, which the results show to be more abrupt than necessary, was . . 0·250 "

A loss also occurs at the entrance, represented by $\left\{\left(\frac{1}{0{\cdot}68}\right)^2-1\right\}\cdot\left(\frac{4{\cdot}49}{2g}\right)^2$. . . = 0·365 "

0·68 being the coefficient of contraction of the water at its entrance to the descending shaft. The remainder, 0·165 "

0·980 "

is a part of the head due to the initial velocity which, it is evident, was not wholly suppressed, the enlargement of the channel under the air chamber being a little too abrupt. This is evident, also, from the readiness with which air was carried past the chamber, implying commotion in the water, which retarded the elimination of the air.

The item 0·365 might have been wholly suppressed by suitably rounding the entrance to the descending shaft. We will therefore reject it in applying the results to the proposed system.

The frictional head proper (0·200) is directly proportional to the square of the velocity, directly as the distance traversed by the water, and inversely as the mean radius of the channel. The other items of head (0·250 + 0·165 = 0·415) are directly as the square of the velocity. The losses in the proposed system of channels will therefore be as follows:

Frictional head, $0{\cdot}200 \times \left(\frac{6}{4{\cdot}49}\right)^2 \times 4 \times \frac{1}{6} = 0{\cdot}238$ foot.

Other losses, $0{\cdot}415 \times \left(\frac{6}{4{\cdot}49}\right)^2 = 0{\cdot}741$ "

Head expended in reducing the water to foam, 1·000 "

Slip $(15{\cdot} - 1{\cdot}979)$, $\frac{0{\cdot}75}{6{\cdot}0} = 1{\cdot}628$ "

Total losses, . . . 3·607 "

$$\text{Efficiency} = \frac{15{\cdot} - 3{\cdot}607}{15{\cdot}} = 76 \text{ per cent.}$$

Similarly, with a head of 30 feet, reducing the air to a pressure of 100 pounds per square inch, the efficiency would be 81 per cent.

St. Paul, July, 1880.

Stability of Oxygenated Water. — Berthelot experimented upon a liquid containing 3·85 grammes of oxygen per litre (225 grains per gallon), to which ·15 gramme (·48 oz.) of sulphuric acid had been added. When exposed to a temperature ranging between 10° and 15°C. (50° and 59°F.), the decomposition continued, during the first month, in a ratio nearly proportional to the time. Afterwards the reaction gradually diminished, and some samples which were prepared in December, 1877, still include measurable quantities of oxygenated water. When the oxygenated water is pure, or very concentrated, the decomposition at first is much more rapid than would be indicated by a simple proportionality to the time. Then comes a certain consecutive period when such proportionality exists; finally, the reaction diminishes nearly as if following a curve with an asymptote. Similar relations are found in the study of ozone, and probably in every exothermic decomposition which is slowly effected in a homogeneous medium. The velocity of the transformation varies in an extraordinary manner with the presence of foreign substances in the liquid. For example, a liquid enclosing 1·66 grammes of active oxygen per per litre, acidified by ·009 gramme of chlorhydric acid, was decomposed with only one-fifth of the rapidity of that which contained the sulphuric acid.—*Comptes Rendus.* C.

EXPERIMENTS ON THE STRENGTH OF YELLOW PINE.

By Prof. R. H. Thurston.

[Presented to the American Association for Advancement of Science, Aug., 1880.]

In a paper read at the Saratoga meeting of the American Association for the Advancement of Science the writer presented the result of a series of experiments on the strength of timber, in which were given several unusual figures.*

To determine how far these results were due to peculiarities of the selected samples supplied from the Navy Yard, and to determine to what extent size affects the resistance, a more extended series of transverse tests were made, and the results of experiments upon yellow pine, of the ordinary market qualities and of various dimensions, are now presented below, as determined in the Mechanical Laboratory of the Stevens Institute of Technology.

In the paper referred to, the modulus of elasticity was given for yellow pine as an extraordinarily high figure. It will be observed that the best wood here described gives also very high values of E, and a comparison of the pieces of the first with these test specimens shows the selected Navy Yard specimen to have been of better material than either of the latter.

Samples marked F_1, F_2, F_3, were from the same plank—a piece of yellow pine cut in Georgia, April, 1879, and tested after several months of seasoning, when it had become thoroughly dry. The three specimens were considered good material. F_3 was not straight-grained and broke obliquely, giving a much lower modulus of elasticity, as well as of mixture, than its companion specimens.

Samples B_1, B_2, B_3, were cut from a stick ten inches square in section, which had been lying under cover, seasoning, nine or ten years.

Numbers 1 to 12, inclusive, were small sticks sawn out of the middle of a plank, originally four inches thick, one foot wide, and twenty-four feet long. A stick was first cut three inches square and twenty-four feet long, which was then cut into strips of varying smaller dimen-

* Among these were several due to printers' errors, which, owing to the illness of the writer, were not corrected in proof. The tenacity of yellow pine, for example, was made 20702 when it should have been given at 20702.

sions. The wood was selected from lumber yard stock, and was considered to be fairly representative of average timber. It was cut in Florida, in October, 1879, and reached Hoboken in January, 1880.

Specimens 1 to 8, inclusive, were too green for use in construction; Nos. 9, 10 and 11 were kiln-dried 56 hours, at a temperature of 130° Fahr., No. 12 was dried 12 hours, at 210° Fahr., at which temperature the pitch exuded from the wood quite freely. Still another specimen, not here recorded, was heated 1½ hours at 420°F., and was somewhat charred. Under test it gave a modulus of rupture, $R =$ 9000..

In the table containing a *resumé* of results is also given the figures obtained in the earlier experiments on selected Navy Yard material, marked J and those of a sample, K, tested by another observer.*

Specimens A, A_1, were picked up in a workshop, and used simply to determine specific gravity; they were probably not the best Southern long-leaved pine, such as it was intended that the samples tested should be.

Calculating $E = \frac{W l^3}{4 A b d^3}$ for heavy loads and considerable deflections, the following figures were obtained for this *pseudo*-modulus:

TABLE II.—*Values of E at one-third to one-half Total Load.*

No.	*E.*	No.	*E.*	No.	*E.*
F_2	2,136,000	1	2,055,000	7	.....
F_3	1,689,000	2	1,776,000	8	2,086,000
B_1	2,394,000	3	2,032,000	9	2,251,000
B_2	2,334,000	4	.....	10	2,869,000
B_3	2,489,000	5	2,272,000	11	2,574,000
		6	2,231,000	12	2,380,000
				Average.....	2,098,000

These figures differ little from those obtained by calculation from the smaller deflections and loads. It was observed that this modulus sometimes decreases with increase of spring, and sometimes increases. As a general rule, the maximum figure was given at one-third, rarely at one-half, and about as often at the beginning of the test. The latter case occurred most frequently with the unseasoned timber.

* *Van Nostrand's Magazine*, Feb., 1880, p. 166.

The following table contains the values of the Moduli of Rupture and of Elasticity deduced from the whole series of experiments:

TABLE I.—*Strength of Yellow Pine Timber.*

Condition.	No. of Test Piece.	Dimensions. l distance between supports.			$R = \frac{W\,l}{b\,d^2}$	$E = \frac{W\,l^3}{4\,b\,d^3\,\delta}$	Weight per cub. ft.	Spec. Grav.
		l ins.	b ins.	d ins.			Pounds.	
Very dry.	F_1	54	2·939	2·946	12,700	.....	41·03	0·66
	F_2	54	2·972	3·008	12,050	1,962,000	45·72	0·73
	F_3	54	3·016	3·000	9,850	1,825,000	40·27	0·64
Old and thoroughly seasoned.	B_1	54	3·046	3·036	13,850	2,178,000	48·89	0·78
	B_2	54	3·016	3·050	13,710	1,949,000	47·14	·75
	B_3	54	3·012	3·017	14,780	2,193,000	46·38	2·74
Too green for use.	1	40	1·285	1·315	12,150	2,171,000	52·85	0·84
	2	40	1·285	1·295	12,530	1,796,000	62·85	1·006
	3	40	1·285	1·295	10,810	1,953,000	.....	.....
	4	40	1·270	1·287	11,350	.....	.....	.....
	5	54	2·930	2·930	10,790	2,427,000	.....	.....
	6	54	2·925	2·925	10,940	2,231,000	.....	.....
	7	24	3·06	0·70	12,000	.....	.....	.....
	8	24½	3·032	0·675	.....	2·279,000	.....	.....
	8*a*	40	3·032	0·675	13,240	2·086,000	.....	.....
Kiln-dried 56 hours at 130°F.	9	54	2·885	2·875	12,100	.....	.....	.....
	10	40	1·240	1·275	17,260	2,564,000	.....	.....
	11	40	1·244	1·274	14,560	2,543,000	54·845	0·88
12 hs. at 210°F.	12	40	1·229	1·242	13,870	2,489,000	51·857	0·83
	K	40	1·23	1·23	14,654	1,892,510	37·72	0·60
	J	54	3·0	3·0	16,740	3,534,727	47·95	0·77
	A	.....	.....	.....	.....	.....	39·64	0·63
	A_1	.....	.....	.....	.....	.....	39·50	0·63
Sapwood from	F_3	.....	.....	.....	.....	.....	35·96	0·57
Average...	.....	.....	.....	.....	.....	2,239,000	.....	.....

On the whole it may apparently be taken as practically true that the deflection is very nearly proportional to the load, far beyond customary limits of strain, and that the modulus is consequently very nearly constant for all moderate deflections.

Thus, from the test of B_1 we obtained

TABLE III.

W.	*E.*	*W.*	*E.*	*W.*	*E.*
50	2,178,000	450	2,288,000	1050	2,363,000
150	2,249,000	650	2,327,000	1250	2,381,000
250	2,259,000	850	2,350,000	1450	2,394,000
				4750	Broke.
				Average.....	2,309,888

When light loads, as one-fourth or even one-eighth the maximum, were imposed for a considerable time, as ten or twenty minutes, the deflection gradually and constantly increased, and on removal of the weight steadily decreased, returning nearly to the original set. Heavy loads, long applied, produced fracture of pieces, the companions to which resisted considerably more when the load was steadily increased up to the moment of fracture. The maximum permanent load was apparently something less than one-third and probably greater than one-half the maximum load which could be sustained under ordinary test.

In concluding this series of experiments upon pine timber, a set of four yellow pine beams of large section was tested to determine the value of the Modulus of Elasticity in large timbers, such are used in heavy work, and also to ascertain whether experiments upon small sticks, such as are usually tested, may be relied upon to give correct values of this coefficient.

The following figures were obtained:

TABLE IV.—*Elasticity of Yellow Pine Timber.*

Size. Inches.			Weight. Lbs. per	Spec.	Max. load.	Max. deflection.	$E = \frac{P^1 \, l^3}{4 \, \Delta \, b \, d^3}$
b.	*d.*	*l.*	cu. ft.	Grav.	P	Δ	Average.
6·187	8·5	144	40·13	0·64	5460	0·7652	110,247 (1)
6·75	8·	200	41·2	0·66	5813	3·8946	895,629
6·875	8·25	150 to 200	.....	.....	1850 to 5900	0·1875 to 2·29	1,768,070 (2)
6·75	8·375	480	45·27	0·72	650	3·234	.....
						Average of all experiments.....	1,387,156

(1) Average of trials at l = 150 to 200.
(2) Average of trials at l = 150 to 200, and beams in different positions.

In this table b, d and l are the dimensions of the cross-section of the beam and the length between supports. In some cases a beam is credited with an average value of E, it having been tested first on its edge and then on its side. Column l gives the distance between the supports. W is the weight of the wood; P is the maximum load in pounds; Δ, the maximum deflection in inches; and E is the coefficient of elasticity.

Nos. 1 and 2 of this lot were of poor quality; the latter, particularly, was somewhat shaky, yet it fairly represents much of the timber which finds its way into important constructions.

The latest work on the strength of timbers which has been consulted by the writer* gives the following values for $E_1 = \frac{W\,l^3}{16\,\Delta\,b\,d^3}$ from which we obtain the proper moduli, $E = \frac{W\,l^3}{4\,\Delta\,b\,d^3}$, as given beside them.

TABLE V.—*Strength and Elasticity of Pine Timber.*

Wood.	Wt.	Spec. Grav.	$R = \frac{l\,W}{b\,d^2}$ †	$R = \frac{l\,W^2}{4\,b\,d^4}$	E	$E = \frac{W\,l^3}{16\,b\,\Delta\,d^3}$	$E = \frac{W\,l^3}{4\,\Delta\,b\,d^3}$
Pitch Pine	39·37	0·63	14,088	2348	735,240	3,020,960	
Dantzic Fir	36·37	0·58	13,806	2301	570,190	2,310,760	
Can. Spruce	30·25	0·48	10,544	1759	771,800	3,087,200	
" R. Pine	34·56	0·55	10,290	1715	588,900	2,355,600	
" Y. Pine	34·87	0·56	8,454	1409	621,050	2,484,200	

From the whole series of experiments, of which the briefest possible statement of the results obtained is here given, the conclusion may be drawn that:

The elasticity of yellow pine timber as used in construction is very variable, the modulus varying from one to three millions, the average being about two millions in small sections, and a little above one and a half millions in large timber (Tables I, IV, V).

The highest values are as often given by green as by seasoned tim-

* Laslett on Timber and Timber Trees. London, 1875.

† Calculated from Laslett's Values.

ber, and that, under sixteen square inches section and fifty-four inches length, at least, the magnitude of the modulus of elasticity is independent of the size of the piece (Table I).

The density of the wood does not determine the modulus; since the figure varies sometimes directly and sometimes inversely with the density, even where the wood is as nearly as possible in the same condition as to seasoning.

A high modulus usually accompanies high tenacity and great transverse strength, but it is not invariably the fact that maximum ultimate strength is accompanied by initial stiffness (Table I).

The pseudo moduli, determined by taking considerable deflections, are usually not greatly different from those determined from small deflections and light loads. The values of these moduli often decrease with increase in deflection (Table III).

An inspection of the woods tested plainly indicates, in the opinion of the writer, that the density of the pines is so considerably modified by the amount of pitch contained in the sap channels that it cannot be regarded as indicative of the strength of the timber. Where quite free from sap the wood usually exhibits increase of strength and elastic resistance to deflection, with increase of density.

The strength of timber, otherwise similar, is greatly affected by its structure, and the resistance offered to stresses applied transversely is greatest when the sections of the timber taken transversely exhibit most nearly vertical lines of grain.

The modulus of rupture by transverse stress varies, for yellow pine, from $R = \frac{2}{3}\frac{W l}{b d^2} =$ 10,000 to 17,000, the highest values being usually obtained from well-seasoned wood. An average value may be taken as $R =$ 13,000 for good timber, which in the formula $W = C\frac{b d^2}{l}$ gives $C =$ 866 pounds, or, practically, $W =$ 9000 $\frac{b d^2}{l}$, for good yellow pine.

The modulus of rupture varies as irregularly, and with as little regard to size or density of the material as does the coefficient for elasticity.

In the use of such materials, the only safe course for the designing and constructing engineer is evidently to adopt a moderate value of

the modulus in proportioning his work, and by careful inspection and test to secure the rejection of all material which is not of good quality.

As has been seen, careful inspection may sometimes lead to the selection of material—like the Navy Yard stock here described—twenty-five per cent. superior to the average of good timber, and fifty per cent. more valuable than the lower grades such as are often sold in our markets.

Reciprocal Displacements of the Halogen Elements. It is well known that chlorine displaces iodine and bromine, and that bromine displaces iodine in metallic combinations; all these displacements are conformable to the thermic theory. The inverse displacements could not be executed under the same conditions, but they may be accomplished under special conditions, either by means of the dissociation of primitive compounds or even, when these compounds are stable, through the formation of secondary compounds, such as the chloride and bromide of iodine, the triiodide or the tribromide of potassium, or even the two chlorides of iron, of mercury, of copper, etc. When the compounds formed by the halogens are dissociated complete transformations are conceivable, following two opposite directions. Berthelot has shown that such transformations are possible in consequence of the dissociation of the secondary compounds, through a very interesting thermal mechanism, which he discovered by studying the inverse displacements of oxygen and of chlorine when united to arsenic, and of oxygen and iodine when united to potassium. It is necessary that the formation of the secondary compounds should set free a quantity of heat superior to the heat which is absorbed by direct substitution in the compounds of the first order. The substitution is also possible if the temperature be raised to the point when the metallic chlorides, bromides and iodides are dissociated, because the halogen element may then act upon a portion of the free metal; the opposite element, being partially removed in the meanwhile, is not present at the moment of cooling to reproduce its primitive combination. This second substitution, however, has not yet been accomplished without the intervention of the accessory influence of air, moisture and the constituents of glass.—*Comptes Rendus.* C.

THE ABSOLUTE ECONOMY OF ELECTRIC LIGHTING.

By Robert Briggs, C.E.

The following article is extracted from the pages of *Engineering*, Oct. 18, 1878, where it appeared in consequence of its being a part of a discussion before the British Association where the experiments on the electric light made by the Franklin Institute in 1878 were referred to. It has been republished at this late day in our pages so that the Journal shall include in its records the fullest statement of the condition of the art of electric lighting at the time when the experiments were instituted.

It is probable, at this time, the best adjustment of quantities of light to dimensions of coils and of wire and to the power expended, will give maximums of light produced per horse-power much in excess of those established by the committee. But the direction of inquiry and the course of argument in considering the results can never differ from the investigations and tenor of the report which the committee and the accompanying paper have established.

"The remarks made by me in the discussion of Mr. Shoolbred's paper on electric lighting, which he presented at the recent meeting of the British Association for the Advancement of Science, can be properly supplemented or extended by an inquiry into the relation of the expenditure of heat in the production of light by means of the burning of coal gas on the one hand or by electrical force on the other. These relations can be looked upon from several points of view. The first of these would be the purely theoretical one, and is based on the absolute heat which would be evolved under the condition of perfect combustion and absolute absorption of heat of coal gas in producing a given light, as compared with the heat which represents the same light as derived from the power expended in producing it.

"There is produced the light effect of one standard candle by the combustion of one-third of a cubic foot of coal gas each hour. That is, this result is that of the tests for quality of coal gas as established by law, but in practice of gaslighting with the usual imperfect burners not much above (if so much as) one-half the quantity of light is obtained. Accepting this quantity it can be asserted that the heat

effect of a cubic foot of coal gas is 690 heat units (pounds of water heated one degree Fahrenheit), and that a candle power of light is represented by 230 units.

"The Franklin Institute experiments did not give the light power claimed by most makers of dynamo-electric machines; they gave as the result only 380 candles of light, as proceeding from one horse-power, while the general claim for at least two of the dynamo-electric machines is nearly five times this value (200 bees Carcel being claimed for the Lontin machine and lamps as given by one horse-power. As each Carcel burner equals 9·6 candles of the English standard, it follows that this claim is for 1920 candles per horse-power). The Franklin Institute experiments also gave 31 to 38 per centum of the whole power as all that appeared in the resistance of the electric arc, which evolves the light, the remainder being expended in friction of machine and in the circuit, being dissipated as heat to the air probably.

"Taking the value of 380 candles as proceeding from one horse-power, we have, the force corresponding to one horse-power equals 1,980,000 pounds raised one foot high per hour—a unit of heat = 772 foot pounds ÷ one horse-power = 2565 units of heat per hour, and 2565 ÷ 380 gives 6¾ units of heat per candle.

"From which it appears that the theoretic expenditure of heat (or force) in producing gaslight is to that in producing electric light as 230 to 6¾, or as 34 to 1, while the theoretic expenditure of heat in producing gaslight is to that of the electric light in the arc alone, is very nearly as 100 to 1. All these are based on the Franklin Institute values; if the figures of M. Lontin are accepted the ratios become five times more favorable for electric lighting.

"But the heat which can be evolved by the burning of coal gas does not represent the heat which appertains to the coal that would have produced the same coal gas. Each pound of gas coal which has undergone the process of destructive distillation will have produced very nearly, on the average, 4 cubic feet of illuminating gas, and there will remain, as a residue of the process of gas making, about 0·85 pound of gas coke, and some 0·04 or 0·05 pound of gas tar, both of which substances are combustible. The quantity of coke, however, is reduced by the necessary use of coke in obtaining the heat for distillation until only 0·55 to 0·60 pound of unconsumed coke remains for each pound of coal originally charged in the retorts. Again, much of this coke is in the condition of dust or very fine breeze, so that practi-

cally only about 0·35 to 0·40 of gas coke is derived in merchantable or useful shape for each pound of coal originally treated; while the coal tar, although it possesses the constituents of a fuel, is not easily burned as such. Ordinary gas coal can be taken to have the value of 15,000 units of heat to each pound, and if it is supposed that from this quantity of heat there be deducted the heat value of, say, 0·6 pound of coke, taken at 13,000 units to the pound = 7800 units, together with the heat value of 0·05 pound of gas tar, taken at 20,000 units to the pound = 1000 units (total deduction 8800), we have 6200 units as the value of the fuel which yielded 4 cubic feet of gas. And, as before, taking each cubic foot of gas as evolving three candles of light, it follows that 517 units of heat will have been expended for each candle of light emitted, and this value should be taken as the expenditure of heat in lieu of the 230 units which the gas would produce after it is manufactured.

"This statement compared with the theoretic heat of electric lighting, as before estimated at $6\frac{3}{4}$ units per candle power, gives the heat in producing gaslight to that of producing electric light as 517 to $6\frac{3}{4}$, or as 76 6 to 1, while the theoretic expenditure of heat in producing gaslight is to that of the electric light in the arc itself as 230 to 1 — with the multiplication of these ratios by five to follow, if M. Lontin's development of light per horse-power is taken in place of that of the Franklin Institute.

"Unfortunately for this statement, in a practical point of view, the production of the electric light by the dynamo-electric machines involves the employment of motive power in the form of the steam engine (I omit to consider the gas engine as the source of motive power, thinking that its adaptation to general use should precede a discussion of its economy in this special application). And in none of the utilizations of natural forces is quite so great waste of original force as in the combustion of fuel in the steam engine. The best of engines can scarcely be claimed to give out a horse-power with less than 2 pounds of coal per hour, while the average of good engines of such size as would be at all available for power to run dynamo-electric machines of ordinary size, cannot be taken to average less than 6 pounds per per horse-power per hour. The former of these weights of coal represents 30,000 units of heat per hour to produce 2563 units of effect, or only 8·55 per centum of the expended fuel, and the latter only 2·85 per centum (one thirty-fifth) of the same.

"Taking this latter value as the practical one, the 6¼ units of heat per candle, which were the theoretic result of the Franklin Institute experiments, becomes 235 units of heat, in fact, needful to produce each candle. Our previous figures have given 230 units of heat as what would proceed from the best consumption of coal gas capable of producing one candle's light, and consequently the comparison of the heat practically demanded to produce electric light by the dynamo-electric machine actuated by the ordinary steam engine with the theoretic heat from coal gas is about 2 per centum against the electric system.

"But the previous figures also give 517 units of heat as what is expended in the making of coal gas for each candle's light, and this value compared with that for the dynamo-electric light with its motive (steam) power is 2·2 times less favorable for the system of gas lighting.

There is another way to look at the practical question. One pound of coal will produce 4 cubic feet of illuminating gas, each foot of which will have three candles' power; then omitting the other products of coal, 0·083 pound of coal represents the fuel expended in giving the light of one candle in the same time by coal gaslighting. Following the previous assumption that 6 pounds of coal will under the boiler of a steam engine evolve one horse-power, and taking the Franklin Institute value of 380 candles per horse-power from the dynamo-electric machine, then 0·0158 pound of coal represents the fuel in this case. This gives the practical relation of expenditure of coal (as fuel) in producing gaslight to that of the electric light under discussion = 5·25 to 1. This last view of the case is practically not an unfair one, for while the coke and the coal tar are not absolutely waste products in process of gas making, they are by no means profitable ones in themselves, and it is questionable if they pay much more than the cost of handling and disposing of them, especially at places where coal for fuel is relatively cheap.

"It must be noticed all through this paper that the assumption has been for the combustion of fuel by an ordinary steam engine and boiler at 6 pounds of coal per horse power, while a moderately good engine with boiler ought and will give a horse-power for 3 pounds of fuel, and the best engines will only require under 2 pounds for the same result, so that all the practical ratios are two to three times less favorable towards the electric system than they might be.

"It remains, therefore, that the most unfavorable statement of the

relative expenditures of heat and fuel practically, of the electric system by the dynamo-electric machines and steam engine, as compared to that of coal gas for equal quantities of light is, at present, 1 to 2·2; while in the processes there will have been burned as fuel one pound of coal under a steam boiler, against $5\frac{1}{4}$ pounds of coal treated in the retort for the manufacture of coal gas. Whether the cost of manipulation of the fires or the retorts, the wear and tear of machinery and engines employed in either processes, the interest upon the prime cost of apparatus, from the fire-places to the points for illumination may be in the same ratio as either the heat demanded or the coal used, is a question for further consideration and for future development.

"Coal gaslighting would seem to have attained nearly to its ultimate development and improvement. Minor advantages of cost of manufacture, and possibly in the direction of quantity of light evolved by a given consumption, can be confidently looked for. The public have been and are habituated to all the defects of the system, and from the beginning to the end they are grave and essential. On the other hand the electric light has the promise of the greatest improvement in methods of production, in its adaptation to defined wants, and in its relative cost, so that the unfavorable view of it which I have here presented should not be taken, and it is far within the limits of probability that the best statement I have presented underrates its possibilities.

"It may be proper to advert here to the low result in candle-power for the electric light found by the Franklin Institute experiments. The power of light emitted by the candle or the gas-burner usually tested by it, is so small that the radiant light from the sides of a dark chamber may be neglected. The measurement of light was taken in all instances from the rays of a standard candle as emitted on the horizontal plane through the centre of the flame. It was found first, that this radiant light upon the walls of a dark box from the electric light was very great, and the means shown in the report of the committee (where it will be seen that only a pencil of light of not over a single degree of aperture was directed into the box or tube carrying the photometer) were found effectual to give a highly satisfactory comparison of the greater with the lesser source of light under investigation. Next it was found in the carbon experiments that there was an apparent unsteadiness of light of great amount emitted from the carbon. As the experiments proceeded it became evident that this unsteadiness was

occasioned by the formation of an arc upon one side of the point (in place of a symmetrical brush), which traversed around the points as they wore away, emitting much the largest part of the light through a small arc of radiation in the horizontal plane, and presenting on one side of the points a brilliant reflection from them, and a corresponding obscuration on the opposite side. This difficulty was met and overcome by the adaptation of carbons of suitable sectional dimension for the current of electricity employed, until a uniform brush, emitting rays of very nearly equal value in all directions, was obtained. The Franklin Institute experiments consequently do not give the value of an apparent maximum of effect but the mean effect from the electric lamps experimented with.

"For a practical datum it may be well to state, in conclusion, that the result of 380 candles per horse-power is, that 90 pounds weight falling one foot per minute represents the power demanded to afford a light of the best spermaceti candle by means of the dynamo-electric system. A man ascending a flight of steps at very moderate rate will have exerted a force equal to three candles. And the results claimed by many makers of dynamo-electric machines are four to five times as good as these.

"The problem of electric lighting to-day is the production of small enough quantity of light with equal economy to that attained for large illuminating effects, and of the distribution into small sources of light of the great light capacity now obtained at a single point of emission. To these ends the intelligence of all electricians is now directed, and the attainment of some measure of success can be confidently anticipated."

Coret's Thermometer.—Coret solders end to end many concentric tubes of different metals, steel and zinc for example. By alternating the joints the differences of dilatation are added, so that the last tube, being connected with a toothed wheel or series of levers, gives a great motion to a needle, sufficient to indicate small fractions of a degree of temperature. The metals being good conductors, the indications are rapid when the metallic mass is placed in contact with any body of which the temperature is desired. The tubes can be concentrated in a space of less than two centimetres (·79 inch). The thermometer is, therefore, very convenient for medical use.—*Bull. de la Soc. d'Encour.*

C.

A NOTE ON THE ARTIFICIAL PRODUCTION OF DIAMONDS BY THE PROCESSES OF DESPRETZ.

By Prof. Edwin J. Houston.

In 1849 Despretz endeavored to produce diamonds artificially by the direct fusion of carbon. For this purpose he combined the heat of the voltaic arc, the sun's heat, concentrated by means of a large lens, and the flame of a powerful blowpipe. The pile consisted of 185 pairs of Bunsen cells. Fragments of nearly pure anthracite, placed in this powerful heat focus, he claims, were observed to melt and fall in drops. He gives an account of these experiments in a note read before the French Academy of Sciences at the séance of June 18, 1849.*

Later, in 1849, he obtained undoubted evidences of the volatilization of carbon by exposing it to the heat of a voltaic arc obtained from a battery of 496 elements, arranged in four parallel series.†

In 1850, by means of a battery of 600 Bunsen elements, connected with a second battery of 135 elements, he succeeded in partially fusing a piece of hard retort carbon, which was thereby converted into pure graphite.‡

By none of these experiments, however, was he able to obtain any positive evidence of the crystallization of carbon.

Notwithstanding these failures he continued his experiments for several years. Abandoning the methods of sudden fusion and volatilization, he tried a number of experiments, all based on the gradual deposition of volatilized material. In one of the most successful of these experiments, the carbon was slowly volatilized in a vacuum, by the continuous discharge of a Ruhmkorff induction coil. A small cylinder of pure carbon placed at one electrode, was gradually deposited in a crystalline state on platinum wires attached to the other electrode. The electrical discharge was continued without interruption for one month, at the end of which time, by the aid of a microscope, octahedral crystals were plainly visible.

* *Comptes Rendus*, Tome 28, p. 755.

† *Comptes Rendus*, Tome 29, p. 48.

‡ *Comptes Rendus*, Tome 30, p. 367.

Apparently no commercial application was ever made of these processes, no doubt on account of the length of time required for the deposition. The present advanced state of electrical science, however, may before long suggest some modifications of these processes that may make them more practicable.

The public interest in the artificial production of the diamond will, I think, warrant my translating the first part of M. Despretz's original paper containing a brief account of the process. It is entitled:

"Observations on Carbon, and on the Difference of Temperature of the Luminous Poles Produced by Induction.*

"The results of the experiments that I had the honor of presenting to the Academy, some few years ago, on the fusion and volatilization of certain bodies, especially carbon, show that it is neither by fusion nor by the sudden volatilization of carbon, that we may hope to obtain this body crystallized.

"We have shown by these experiments that pure carbon melted, and that the diamond melted, form only amorphous graphite; that carbon suddenly volatilized on the walls of a flask gives only a dark powder without any appearance of crystallization.

"These experiments on the fusion and volatilization of carbon are now repeated every year in the course on chemistry and physics at the Sorbonne. We can obtain by the heat of the arc a number of crystallized bodies. I hope I may return to this point. The same results would probably be obtained for carbon if we had crucibles less fusible than this substance, which we do not possess. I have, therefore, had recourse to another process. The process which has given me the best success is founded on a gradual volatilization produced by induction currents.

"I took a flask with two tubulures, arranged as for the electrical egg; to the lower rod I attached a cylinder of pure carbon, a few centimetres in length and one centimetre in diameter. I attached to the upper rod a dozen thin platinum wires; I produced a vacuum in the flask; then, the distance between the wires and the carbon being from 5 to 6 centimetres, I caused to pass the current of an induction apparatus constructed by M. Ruhmkorff, and which has been described in several notes presented to the Academy. The arc was reddish from

* *Comptes Rendus*, Tome 37, p. 369.

the carbon to within a short distance of the platinum; the portion which enveloped the extremity of the platinum wires was of a bluish-violet.

"This arrangement of apparatus was always adhered to. We placed the bundle of platinum wires above, in order not to confound the minute sparks from the carbon, with the crystals which we wished to form.

"The pile was composed of four Daniell's elements, connected two by two.

"The experiment continued uninterruptedly for a month, excepting the time necessary to recharge the pile. There was deposited a thin black layer of carbon on the wires. This layer, viewed by a lens, did not present any very distinct appearance; with a compound microscope, with a magnification of about thirty times, it presents several interesting points.

"I saw over the wires, and particularly at the extremities, particles separated one from another, which seemed to belong to the octahedral system.

"I saw, also, on the black layer, but none at the extremities, several small octahedra resting on a summit.

"I repeatedly examined the wires, and always found the same things.

"An able and skilled crystallographer has recognized black octahedra, truncated at the extremities, and little white octahedra resting on a summit.

"I did not previously inform my colleague, M. Delafosse, what I observed.

"I substituted for the wires a polished platinum plate, $1\frac{1}{2}$ centimetres in diameter; although this experiment continued in activity for almost six weeks, yet there was no deposit of crystals on the plate. The plate was covered over at least half of its surface with almost circular curves, with radii somewhat larger than that of the plate; each of these curves was painted with one of the colors of thin films. We saw here and there small greyish-white spots of powder, which appeared to be the result of the momentary adherence of isolated deposits.

"In another experiment I fixed a cylinder of pure carbon to the positive pole of a feeble Daniell pile, and to the other pole a platinum wire; I then plunged the two poles in water slightly acidulated. The

experiment continued for more than two months; the negative pole was covered with a black layer.

"Nothing was discovered in this layer by an examination with a microscope.

"I requested M. Gaudin, known to the Academy by different researches, to try both products on hard stones.

"He proved, in my presence, that the small quantity of material that surrounded one of the dozen wires of platinum, mixed with a little oil, sufficed to polish in a short time several rubies.

"The black powder deposited in the humid way, although much more considerable in quantity, required more time to produce the same polish.

"We know that the diamond is the only body which polishes the ruby; therefore M. Gaudin has not hesitated to consider both materials as the powder of the diamond.

"I have made a great many experiments during two years; I give here the two which afford the most interesting results."

In connection with the above we note a communication to the French Academy of Sciences,* from M. Lionnet, in which he claims to have made, in 1846 and 1847, experiments on the crystallization of carbon. These experiments, since forgotten, were recalled by a communication of Chancourtois† to the Academy. M. Lionnet claims to have used the following process: A voltaic couple, formed of platinum and tin, was plunged in a small vessel filled with carbon bisulphide, under the action of the weak current so developed, decomposition of the electrolyte occurred, the sulphur combining with the tin, while the carbon, the author claims, was deposited in a crystalline condition on the bottom of the vessel. It would seem that if deposited at all under these conditions, it would be on the surface of the platinum.

Central High School, Philadelphia, Aug., 1880.

Lunar Geology.—J. Lauderer has submitted to the Academy a work in which he seeks to determine the lithologic character of our satellite. He thinks that the density of the moon, and the angle under which it polarizes the light of the sun, are such as to show that the materials of the surface are analogous to those of the silicate rocks.—*Comptes Rendus.* C.

* *Comptes Rendus*, Tome 63, p. 213. † *Comptes Rendus*, Tome 63, p. 22.

THE PERKINS ENGINE.

The system of steam engine and boiler construction so perseveringly developed by Mr. Loftus Perkins has during the past few years attracted considerable attention, and a strong desire has been expressed in many quarters to have made public some really definite data as to the capabilities of the system. Under these circumstances the report by Mr. F. J. Bramwell, which is hereto attached, will be read with much interest. This report deals with the results of a trial made by Mr. Bramwell of the Perkins engines fitted to the yacht *Anthracite*—a vessel whose recent transatlantic voyage has been noticed in this journal. The trial lasted twelve hours, and appears to have been conducted throughout with great care and under rigorous conditions, and the results so far as recorded are no doubt perfectly trustworthy. It will be seen by the report that during the period of 11 hours and 10 minutes the engines developed on an average 80·55 horse power, while the average coal consumption during the whole trial (including getting up steam) was 1·83 lb. per indicated horse power per hour, the consumption during 8 hours 55 minutes, during which the engines were developing 80·9 horse power, being estimated by Mr. Bramwell as 1·7 lb. per indicated horse power per hour. These are undeniably excellent results, but they are scarcely so good as engineers have been led to expect from the Perkins engine working with a boiler pressure of 340 lbs. to 370 lbs. per square inch.

It is somewhat unfortunate that Mr. Bramwell in testing the Perkins engine should have adopted the coal consumption as the sole measure of economy, as by his doing so it is rendered impossible to separate the performance of the engine and boiler. It is possible that Mr. Perkins may have preferred his system of engine and boiler construction tested as a whole; but however this may be, it is to be regretted that during the trials of the *Anthracite* observations were not made as to enable an opinion to be formed of the practical value of steam at very high pressures, apart from any question of boiler efficiency. Under the circumstances, all that can be done is to attempt to form some idea of what the efficiency of the boiler really was. In Mr. Bramwell's report the dimensions of the boiler of the *Anthracite* are not recorded, but through the courtesy of the Perkins Engine

Company we are able to give them. The boiler, then, is 14 "sections" in width, while there are 7 rings of tubes in the firebox and 10 layers of tubes above, the straight tubes above the firebox being 4 ft. 7 in. long. The tubes are 3 in. in diameter outside and 2¼ in. inside. A reference to the engravings of the Perkins boilers of the yacht *Wanderer*, which we published on page 472 of our 28th volume, will make the general arrangement clear. The boiler of the *Anthracite* has altogether 633 square feet of heating surface and 15 square feet of firegrate, the ratio of grate to heating surface being thus 1 : 42·2. The total coal consumption recorded by Mr. Bramwell is 1697 lbs. during the trial of 12 hours 3 minutes, it being thus at the rate of 9·4 lbs. per square foot of grate surface per hour, or 0·222 lb. of coal per hour per square foot of heating surface. The boiler was thus very easily worked, and considering the high quality of coal used, and the fact that the feed was drawn from the hot well, there is every reason to believe that the evaporation per pound of coal was high. Probably we shall be erring on the side of moderation if we put down the evaporation at 10½ lbs. of water per pound of coal.

The mode of trial adopted by Mr. Bramwell does not admit of the coal used in getting up steam being separated from that actually expended in making steam during the run, but for our purpose we may assume the coal consumption estimated by Mr. Bramwell as taking place between 7.50 A.M. and 4.45 P.M., viz., 1·7 lb. per indicated horse power per hour. With an evaporation of 10½ lbs. of water per pound of coal this would give a consumption of 1·7 × 10·5 = 17·85 lbs. of steam per indicated horse power per hour. This is a very low consumption, particularly when the moderate size of the *Anthracite's* engines is considered, but we cannot help thinking that it would be very closely approached, if, indeed, not equaled, by a compound engine of the modern type working with steam at 80 or 90 lbs. pressure. In saying this it is only fair to add that we consider the *Anthracite's* engines were not tested under circumstances calculated to show the highest economy as far as the consumption of steam per horse power is concerned. We believe that they would have done better if they had been more heavily loaded; as it was, the power developed (notwithstanding the high boiler pressure) only about equal to that which would have been developed by an ordinary compound marine engine with the same size of low-pressure cylinder, working at the same piston speed, and with a boiler pressure of 70 or 80 lbs. per

square inch. An inspection of the indicator diagrams taken from the engines of the *Anthracite* by Mr. Bramwell, shows that excessive throttling took place between the boiler and the high-pressure cylinder, the difference between the boiler pressure and the initial pressure in the cylinder being rarely less than 170 lbs. per square inch. Thus, with a boiler pressure of 340 to 370 lbs. per square inch, the initial pressure in the high-pressure cylinder was always under 200 lbs. Of course the low power at which the engines of the *Anthracite* were worked during Mr. Bramwell's experiments was favorable to the performance of the boiler, and it is quite possible that, taking the engine and boiler together, the load may have been well chosen to secure a low fuel consumption. At the same time, the work demanded from the engines and boiler during the trial was undoubtedly much easier than that which steamship machinery is generally called upon to perform in regular practice.—*Engineering.*

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37 Great George Street, Westminster, S. W.
June 28, 1880.

To the Directors of the Perkins Engine Company, Limited.

Gentlemen:—In accordance with your desire, as communicated through Mr. Loftus Perkins, I, on Saturday the 22d May, made a trial of the Perkins patent engine fitted on board the screw steam yacht *Anthracite*, preparatory to her leaving England on her voyage to New York.

You are of course perfectly well aware of the nature of the engines and boilers of the *Anthracite*, but in order that this report may be more readily followed, I think it well to state, in the report itself, the leading particulars of the machinery of that vessel.

The engines are of the direct-acting inverted type with surface condensation. Two cylinders only are used, but the after cylinder has two diameters of bore; the upper and smaller one is the high pressure, and receives the steam from the boiler during the first half of the down stroke, the lower and larger diameter, is the medium or intermediate, and is supplied at the up stroke with the steam, which in the high pressure did the work of the preceding down stroke. The exhaust from the bottom of the after cylinder passes into a chamber, from which is afforded the supply to the low pressure (the forward) cylinder, and from this arrangement there is obtained in two cylinders an expansion of thirty-two times.

The distribution of the steam in the after cylinder is made by three lifting double-beat valves, the upper faces of these valves being, however, divided into two sections. The valve stalks rise and fall by the action of eccentrics, which control the motion of the stalks downward as well as upwards, the stalks being loose in close-topped sockets in the valves, so that after the valves are seated the stalks can recede from them. The distribution of the steam to the low pressure cylinder is made by an ordinary slide valve with an expansion valve on its back; this latter valve is worked off the prolongation upwards of the circulating pump rod. The surface condenser is composed of a number of close-topped, galvanized, wrought-iron tubes, standing vertically from a tube plate, and having within them smaller tubes open at both ends, and proceeding upward from a lower tube plate, so that the water from the seat passes up through the central tubes, and down the annular spaces to the inlet of the circulating pump.

The exhaust steam is admitted into the body of the condenser, and comes into contact with the exterior of the close-topped tubes, the condensed steam being drawn off by the air-pump, and returned to the hot well which surrounds the upper part of the condenser. The space between the high pressure piston and the upper side of the intermediate piston is in connection with the chamber which supplies the low pressure cylinder. The circulating pump is worked by a beam off the low pressure piston rod, and the air-pump is worked by a similar beam off the intermediate cylinder piston rod. The feed pumps and bilge pumps are worked off the cross heads of the circulating pump and of the air-pump. The reversal is effected by a link motion.

The cylinders and their covers are heated by steam circulating through wrought-iron pipes cast into the thickness of the metal, and are very efficiently clothed so as to prevent loss of heat.

The boiler is the well known Perkins boiler formed of successive horizontal rows of wrought tubes (3 inches external diameter) connected at frequent intervals by vertical thimbles, the whole series being contained in a wrought-iron double casing having the space filled in with vegetable black. The water gauges, one in the boiler and one in the engine room, are made of flat plates of mica secured in frames. The boiler is supplied with distilled fresh water. There is a still fitted with a coil, and having its steam pipe in connection with the condenser, by which the store of water can be distilled over for use.

With respect to the dimensions of the engine, I was furnished at

my request by Messrs. Hawks, Crawshay & Sons, the builders of the engines, with the working drawings. These drawings show the high pressure cylinder to be 8 inches bore, the intermediate 16 inches bore, and the low pressure 23 inches bore, but I was informed by Mr. Perkins that the cylinders were all somewhat smaller than the foregoing dimensions. He has now sent me the gauges, and these give the high pressure cylinder at $7\frac{3}{4}$ inches diameter, the intermediate as $15\frac{13}{16}$ inches, and the low pressure as $22\frac{13}{16}$ inches. The stroke in both cylinders is 1 foot 3 inches. The diameter of the piston rods (the areas of which have to be deducted from the area of the intermediate piston, and from that of the underside of the low pressure piston) is $2\frac{3}{4}$ inches.

My principal assistant was on board the *Anthracite* on the Friday, and he informed me that the fire was let out at about 2.30 P. M. on that day, and as the result the boiler and water were practically cold when the fire was lit on Saturday morning.

Preparations for the trial had been made by weighing out 50 cwt. of "Nixon's navigation hand-picked lumps" into fifty 1 cwt. sacks. These were ranged on deck. The bunkers, which were full, were sealed up both above and below. A spring balance was hung up on deck, close to the stokehold hatch, and one of my assistants caused each sack of coal to be reweighed just before it was lowered for use. The gross weight was taken, and the sacks were afterwards separately weighed so as to obtain the net weight of the coal.

Fifty pounds of dry wood were served out and two sacks of coal, and with these the fire was laid (the grate has an area of about 15 square feet). The fire was lit at 6.28 A. M. Steam was up and the engines were turned round at 7.18 A. M. The height of water in the boiler gauge was noted, and also the height in the hot well, the still cock being shut, was sealed in that position. The steam stop valve was sealed in its wide open position. The engines were started, and the vessel got under way at 7.20 A. M. The throttle valve was put into the position which the engineer knew, from experience, would cause the engines to run at about 150 revolutions per minute after they became thoroughly heated up, and the handle was sealed into this position, the link motion being in full gear ahead. The engines were provided with a Harding's counter, such as is used in the Navy, and there were pressure gauges to show the boiler pressure, and the pressure in the chamber supplying the low pressure cylinder, and the condenser was provided with a vacuum gauge. Four Richard's indicators were

fitted, viz.: one to the high pressure end of the after cylinder, one to the intermediate end of that cylinder, one to the top and one to the bottom of the forward, the low pressure cylinder.

The first set of diagrams was taken at 8.22 A. M. The first reading of the counter at 8.30 A. M. From this time until 5.45 P. M. the counter was read at the hours and half hours, and sets of diagrams were taken at the quarter past the hour, and at the quarter to the hour. The time when each sack of coal was lowered into the stokehold was noted, and also the time when the stoker commenced to use the contents of each sack.

The last shovelful of the fifteenth sack was put on at 5.18 P. M., and it was decided to stop the trial as soon as the coal then in the fire was exhausted.

I determined to let the engines run on until they stopped of themselves, and to take indicator diagrams, first at each quarter of an hour and then at each five minutes during the time they were gradually stopping. The quarter hour diagrams were taken until 6.30 P. M., when the engines were making 124 revolutions, and the five minutes diagrams were taken until the engines came to a stand at 7.23 P. M. or 12 hours 3 minutes after their start in the morning. The water in the boiler was pumped to the same level in the gauge as that at which it had stood in the morning and the height of water in the hot well was noted.

The mean revolutions from 8.30 A. M. to 6.30 P. M., 10 hours, were 130·77 per minute, and from the first start to the same time being 11 hours 10 minutes, the mean revolutions were 130·4 per minute.

An experiment was made as to the transmission of heat through the boiler casing. This was carried out by placing the bulb of a thermometer in contact with the top of the casing, the bulb being covered over with cotton waste; the result was that at the end of one hour the thermometer stood at 125 degrees Fahr.

From the start at 7.20 A. M. to 6.30 P. M., 11 hours and 10 minutes, the engines developed an average gross indicated horse-power of 80·55, but from 6.30 to the time, 7.23 P. M., that the engines stopped of themselves from the fire having burnt itself out, the power was of course gradually diminishing. This being so I have calculated the whole work from first to last in foot-pounds; these amount to 1,828,291,466 foot-pounds, equivalent to 923·38 horse-power if exerted for one hour.

I estimate the 50 pounds of wood as of about one-third the value of coal as fuel, say .	17 lbs.
The coal 15 cwt., . . .	1680 "
	1697 "

The gross indicated horse-power developed during the trial being equivalent to 923·38 horse-power exerted for an hour 1697 ÷ 923·38 = 1·83 pounds of coal per horse power per hour, *including the coal used in getting up steam.*

As a check upon the foregoing from the time when the first shovelful of the fourth sack of coals was put on the fire, namely, at 7.50 A. M. to the time when the first shovelful of the fifteenth sack of coals was put on the fire, namely, 4.45 P. M., *i. e.*, 8 hours 55 minutes, the engines exerted an average of 80·9 horse-power; this gives the consumption per horse-power per hour at 1·7 pounds, assuming the fire was uniform at the commencement and end of these times. The loss of water for the whole 12 hours was 23½ gallons.

The engines worked with the most remarkable smoothness and regularity, as with the exception of tightening up the bolts of two glands about an hour after the start, there was not a spanner or hammer or any tool used about the engines during the 12 hours the ship was under way, nor was there a single handle connected with the engines shifted. The link-motion was in full gear the whole while, and the stop valve and throttle valve remained, as I have said, sealed up and unmoved.

Water was allowed to circulate on the thrust-block, but there was not a heated bearing anywhere. The amount of lubrication was small, involving an expenditure of about one gallon of lard oil, while cylinder and slide lubrications are in the Perkins system inadmissable and with the metal used unnecessary.

The engines were thoroughly steady, no straining or racking of any kind, in fact it is impossible for any pair of engines to have worked in a more thoroughly satisfactory manner, so far as all external evidence of working was concerned, and there were no sounds to lead to any other belief than that of all being satisfactory within.

I hope on the return of the *Anthracite* from America to have an opportunity of seeing the engines opened, and of thus observing their condition after some thousands of miles of steaming, and I should also be glad to have an opportunity of retesting the consumption.

At the conclusion of the trial my assistants took away the four indicators and the spring balance with which the coals were weighed. All these have been tested with the result that the balance and the 100 pound spring (used in the high-pressure cylinder indicators) and some of the lighter springs, are absolutely accurate, and that the variations in the others are too trifling to call for any allowance in calculating the mean pressures.

It may be well to state that the mean pressures of the various diagrams (of which there were 128 in all) have been ascertained by dividing the areas of the diagrams, obtained with the planimeter, by the lengths of the diagrams. This is a thoroughly accurate mode, while the plan commonly followed of measuring the heights of the diagrams at a number (usually ten) of places is one which ordinarily gives a pressure in excess of the truth.

It would be an investigation of considerable interest in an engineering point of view if a vessel fitted with first-rate compound engines of the ordinary construction, and working, say, at 70 pounds pressure in the boiler and indicating something about the same power as those of the *Anthracite*, viz., from 70 to 90 horse-power, could be tried in a precisely similar manner to that in which the *Anthracite* was tried.

In conclusion I wish to say that I esteem myself particularly fortunate in having obtained the friendly co-operation during the run of Mr. William Rich, of Messrs. Easton and Anderson, whose long experience in engine trials rendered his assistance of the greatest value, and to whom I beg leave to express my best thanks. I have his authority for saying that he entirely concurs in this letter of report.

I am, gentlemen, your obedient servant,

(Signed) F. J. Bramwell.

Ammonia in Vegetables.—H. Pellet has lately found appreciable quantities of ammonia in various kinds of grain, as well as in beet root. In wheat the weight of ammonia is one-tenth as great as that of the ashes. He thinks that magnesia and phosphoric acid enter into vegetables under the form of an ammoniacal magnesian phosphate, which is very soluble in all vegetable acids. He is now studying the effects of ammoniacal manures, and of nitrogen, under different forms, upon the amount of ammonia in vegetables.—*Comptes Rendus.* C.

THE MANUFACTURE OF BESSEMER STEEL AND INGOT IRON FROM PHOSPHORIC PIG.

By C. B. Holland and A. Cooper, Sheffield.

Read before the Iron and Steel Institute, May, 1880.

Before entering upon the subject of our paper it might not be out of place to consider for a moment what is steel and what is ingot iron. Steel has been defined as "an alloy of iron and carbon which is capable of being cast whilst in a fluid state into a malleable ingot," and all other elements usually found in the steel of commerce, such as silicon, sulphur and phosphorus, may be regarded as impurities, and are more or less hurtful. In like manner, ingot iron may be defined as an iron which is capable of being cast whilst in a fluid state into a malleable ingot, and other elements found in it (including carbon) may in this case also be regarded as impurities. It follows, then, that those steels and ingot irons are the best and purest which contain the noxious elements in the least quantities, no matter whether they be produced from the finest brands of Swedish and hematite, or from common iron containing from $1\frac{1}{4}$ to 2 per cent. of phosphorus. And we think all will agree, if it can be shown that steel and ingot iron can be produced from the latter kind of pig of the same chemical composition, and capable of standing the same mechanical tests as that produced from the purer irons, that one is as good as the other for all purposes. It is not our intention to occupy the time of the Institute by referring to any of the numerous papers that have been written, and the theories that have been propounded, during the last eighteen months, on the dephosphorization of iron by the Thomas and Gilchrist process, interesting and instructive as many of them are. It will be sufficient to say that notwithstanding the great strides that had been made in the development of the process at the works of Messrs. Bolckow, Vaughan & Co., under the able direction of Mr. Richards (who must always be regarded as one of its earliest pioneers), and the very satisfactory results obtained by that company in the manufacture of steel from Cleveland pig-iron up to the early part of November last, before we had seen the process in operation, there appeared to us certain difficulties which we feared would greatly retard its successful

working from a commercial point of view. The first of these may be regarded as a technical one, and had reference to that part of the operation now well known as the "after-blow." Assuming, as we did, all the metalloids, with the exception of phosphorus and sulphur, to be oxidized before the commencement of this period, it seemed doubtful to us whether this would be practicable (having no definite point at which we could safely stop blowing corresponding to the drop of the carbon flame in the ordinary process) to burn out the whole of the phosphorus regularly, without sometimes carrying the operation too far, and thereby oxygenating the charge. And this, as all steelmakers will agree, is very apt to give trouble. Again, we had our misgivings about the gathering at the nose, concerning which we had heard so much, and the delays which we thought must necessarily result from the indispensable and repeated turning down of the converter for sampling. It was at this time (early in November last year) that we were invited to see the process at the Hoerde Works in Westphalia, and through the courtesy of Mr. Pink, the manager of the Steel Works, our representative was not only shown the process in operation, but every information respecting the difficulties that had been experienced up to that time, and the means which had been employed to overcome them, was very kindly given to him by that gentleman. From the working at Hoerde it was apparent that the phosphorus was eliminated with regularity—there were no violent reactions on the addition of the spiegel, showing that the metal was not oxygenated to any great extent, and the steel made was of a mild quality, and very malleable. On November 20th we commenced to work the process in Sheffield, using a mixture of White Lincolnshire and No. 4 forge irons. By sampling during the after-blow, we were enabled not only to remove the phosphorus in a very satisfactory manner, but also to make good and malleable steel; but the gathering of the slag and metal at the nose of the converter at first proved such an obstacle to rapid working, that although we employed men with long bars to fettle after each operation, at the end of from twelve to eighteen blows we were compelled to stop, allow the converter to cool down, and cut out the accumulation. At this early stage we were of opinion that by increasing the area of the nose we should get a decreased pressure of gases, and consequently the slag and metal would not be carried up so high, and that this would remedy the evil. Our experiment proved to us conclusively the fallacy of this, for after altering the shape of our con-

verter so that the area of the mouth was doubled, and lining up with basic brick as before, although we worked under precisely the same conditions, this converter was completely slagged up to the nose, and was unfit for further work after ten blows, simultaneously with the other converter and with the mouth of usual size, lined with basic bricks. We tried admitting blast at the throat, with the view of burning the carbonic oxide, and so increasing the temperature at this point, but the results were not sufficiently encouraging to justify our following up the experiment. In the succeeding week we lined our converter nose with brick made of silicate of soda and limestone, the other with ordinary fireclay bricks, contracting both at this point to a diameter of about 20 inches, or to about one-half the original area. In both cases we perceived at once a great improvement through the reduced size, the converters retaining their heat very much better than before. The slag still adhered to the first-mentioned slightly. It was easily removed by bars, but, unfortunately, usually carried a portion of the very brittle silicate of soda and limestone brick with it, and this form was abandoned on that account. The other converter with the fireclay bricks gave better results, and we have since used them regularly. What little slag adhered could be removed without any material injury to the lining. Although the common fireclay bricks then used wasted considerably, numerous experiments proved that the amount of silica carried down into the bath from them was too small to do any harm, and as the lining at this part was about 15 inches in thickness, we were able to get regularly from 30 to 40 blows before it got too thin. Thus, as far as the immediate nose was concerned, the difficulty seemed at an end, but we soon found that a great accumulation took place just below the junction of the fireclay bricks with those of the basic material, and also along the sides of the converter, in the form of a ridge of slag and metal left little by little on each turning down for the purpose of sampling. It seemed to us that to remedy this evil the simplest plan was to avoid testing as much as possible, if not altogether. All our results had shown that notwithstanding the after-blow the fully blown metal was not nearly so much oxygenated as at the end of the ordinary blow in the hematite process. Numerous analyses gave us the impression that this was due to the presence of manganese in the mixture we were then using, containing as it did about ·75 per cent. of this metal, and we found invariably

that when we started with this quantity there always remained from ·1 to ·2 at the expiration of the after-blow.

The following analyses show how much more readily (during this part of the operation) the phosphorus is attacked than the manganese.

	At the drop of the carbon flame.	At the end of the after-blow.
Blow 108 Phosphorus,	·883 per cent.	·062 per cent.
" Manganese,	·443 "	·111 "
Blow 136 Phosphorus,	1·090 "	·044 "
" Manganese,	·183 "	·147 "
Blow 166 Phosphorus,	·890 "	·081 "
" Manganese,	·435 "	·194 "

These, amongst other results of a similar kind, led us for a time to think that it might be possible to eliminate the whole of the phosphorus by increasing the amount of manganese in the charge, and blowing with the spectroscope until the absorption bands—which one of our greatest authorities, Mr. Watts (see Roscoe's *Chemistry*, vol. ii, part 2, page 77), on the use of this instrument has attributed to the oxides of this metal—had disappeared, for although our previous experience with mixtures containing ·75 manganese had shown us that the bands always disappeared from the spectrum at the drop of the carbon flame, at which from ·2 to ·4 still remained, we thought it likely (assuming the above theory to be correct) that with a larger quantity we should be able to get rid of the phosphorus before these bands vanished. Accordingly, by means of ferro-manganese we increased the proportion of manganese in charge No. 165 to about 1·75 per cent. At the drop of the carbon flame, when the bands disappeared, we found the composition to be:

Sulphur,	·118 per cent.
Phosphorus,	·955 "
Manganese,	·817 "

The sample taken at this period hammered well, but, on testing in the usual way, proved very brittle indeed, and the fracture did not show the characteristic appearance indicating the presence of phosphorus, but resembled that of a very hard steel. On turning up the converter again for a further blow of thirty seconds certain bands reappeared in the green portion of the spectrum for three or four seconds only; the composition at the end of this period was found to be:

Sulphur,	·155 per cent.
Phosphorus,	·831 "
Manganese,	·612 "

The sample taken and treated in the same way as before was still exceedingly brittle, and resembled the former one. Again the converter was turned up, and for the space of one or two seconds only these bands again flashed across the spectrum, after which they were not observed during the remainder of the after-blow, although most carefully looked for. At the end of this period the test made was still hard, though much milder than before, and had the following composition:

Sulphur,	·132 per cent.
Phosphorus,	·460 "
Manganese,	·576 "

The charge was then blown for a further sixty seconds, and as the sample, which was very malleable, did not harden, thinking that the fine crystalline appearance of the fracture on breaking was due to manganese, the heat was cast without the addition of spiegel or ferromanganese. It showed no disposition to rise in the open-top ingot moulds in which it was cast, and a tire 2 feet 8 inches inside diameter, made from one of the ingots, all of which hammered very well indeed, deflected 8 inches before breaking. Analysis of this steel or ingot iron, which showed that we had not carried the process quite far enough, gave the following composition:

Sulphur,	·114 per cent.
Phosphorus,	·146 "
Manganese,	·440 "

From these results we drew the following conclusions: That the absorption bands usually seen in the spectrum of the Bessemer flame are due to carbon, and that manganese bands (very similar in appearance to those of carbon) are apparent only when that metal exists in quantities of about 5 per cent.; and further, that we could not hope, through the agency of this metal to determine upon any fixed point indicated by the spectroscope at which we could safely stop blowing, satisfied that the whole of the phosphorus was removed. But we had before noticed that with regular charges and conditions the after-blow was of very constant duration, and the results of the blow showed us not only that with 1·75 per cent. of manganese in the charge, in order to be quite sure of eliminating the whole of the phosphorus, we might safely blow rather longer (without risk of oxygenating) than the time actually required to effect this purpose, and thus avoid sampling; and afterwards, for rails, add a low spiegel or plate iron to carbonize; but

also that, if an ingot iron were required, it could be readily produced by the means described, without any such addition. Want of an iron containing anything like the amount of manganese prevented us from following up these results for some time, but meanwhile, with mixtures such as we had, containing ·75 per cent., we tried the effect of blowing after the addition of the spiegel, until the carbon bands, as seen through the spectroscope, had nearly vanished. The chemical analyses and results of a rolled bar from each of three such blows, tested, gave the following results:

Blows.	C. Carbon by combustion.	Sulphur.	Phosphorus.	Manganese.	Breaking Strain. Tons.	Elongation in 10 in. Per cent.	Reduction of area. Per cent.
·314	·040	·065	·030	·356	24·20	26·875	51·78
·329	·050	·045	·051	·240	26·48	29·375	65·59
·330	·038	·069	·035	·266	24·18	26·250	59·04

Three more blows made, amongst others, in the same manner, some weeks afterwards, gave the following results:

Blows.	C. Carbon by combustion.	Sulphur.	Phosphorus.	Manganese.	Breaking strain. Tons.	Elongation in 10 in. Per cent.	Reduction of area. Per cent.
·689	·061	·096	·051	·345	Not tested.		
·703	·073	·091	·027	·370	24·49	31·25	49·79
					24·62	27·50	56·06
·705	·101	·070	·047	·468	Not tested.		

The metal in all cases gave no trouble in casting into ingots (some, indeed, were cast in open-top moulds from the top), and it was very malleable. Specimens of bars from blows 314, 329, 330 and 703 plunged into cold water at a red heat—some of which were afterwards bent and some twisted, cold—are exhibited. Having at length obtained some iron containing about 2 per cent. of manganese, a charge of this was blown alone, and at the end of the after-blow of 130 seconds' duration, as the test taken was very malleable, and would not harden, the charge was cast into ingots without any addition whatever. The chemical composition of this charge and the results of the mechanical tests are as follows:

Blows.	C. Carbon by combustion.	Sulphur.	Phosphorus.	Manganese.	Breaking strain Tons.	Elongation in 10 in. Per cent.	Reduction of area. Per cent.
·748	——	·075	·030	·235	23·49	30·00	72·04
					23·49	28·25	70·01
					23·37	27·50	74·12

The heat as before gave no trouble in casting, and the steel was very malleable when worked at a high heat. Samples of the pieces submitted to tensile strains, together with bars plunged into cold water at a red heat, and afterwards twisted and bent cold, as well as ordinary cold bends, are exhibited.

A second charge was treated in exactly the same way, except that at the end of the after-blow 15 cwt. of white hematite pig-iron were added in lieu of spiegel. The resulting steel gave no trouble in casting, and an ingot, hammered to test its malleability, worked very well. Analysis of the steel produced gave the following results:

C. C.	Si.	S.	P.	Mn.
·55	Not estimated.	·107	·151	·612 per cent.

It will be noticed that the phosphorus and manganese are higher—the former than it ought to be, the latter than one would have expected to find, after the addition of a non-manganiferous pig; but as the charge of white hematite was melted in a cupola which had only just before contained a 20 per cent. spiegel charge, we think it likely that a small quantity of this must have remained behind and come out with the white iron. With respect to the phosphorus, the mixture was one with which we had little experience. It was also the last charge from the cupola, and, unfortunately, nearly a ton heavier than it should have been, which circumstance was not observed until it was poured into the ladle. And, although it was blown for 130 seconds after the disappearance of the carbon bands, exactly the case as blow 748, there is no doubt that it was underblown, as the metal, before the addition of the white iron, contained as follows:

S.	P.	Ma.
·125	·147	·360 per cent.

For some time past, except in the case of the first two or three blows from a new mixture, when samples have been taken to determine the length of the after-blow, we have blown to time, and all

testing during the operation has been dispensed with. It is true that our early results were not all satisfactory, but latterly since we have used a mixture containing about C.C. 4·0 per cent., Si ·5 per cent., S ·2 per cent., P 1·4 per cent., Mn 1·0 per cent. in the converter, we have succeeded very well, as the results below will show. During the week ending April 10th, twelve test pieces, taken at random from the week's work, contained of phosphorus as follows:

	Per cent.		Per cent.		Per cent.
No. 1,	·103	No. 5,	·065	No. 9,	·111
" 2,	·067	" 6,	·074	" 10,	·054
" 3,	·040	" 7,	·073	" 11,	·074
" 4,	·051	" 8,	·052	" 12,	·048

And in the week ending April 17th, when not a single sample was taken during the operation, except in the case of the experimental blow 748, the average amount of phosphorus contained in 36 blows, all of which were analyzed, was ·056 per cent., the highest being ·101 per cent., and the lowest ·019 per cent. The composition of this quality of steel has been in other respects very regular, the analyses and results of a test piece, 2 inches long and ·533 inches in diameter, being as follows:

Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Breaking strain. Tons.	Elongation. Per cent.	Reduction of area. Per cent.
·40	—–	·40	·085	·662	39·75	20·25	31·84

Since the sampling during the operation has been dispensed with there has been comparatively little trouble with the slag adhering to the sides of the converter, and the wear of the lining has been practically uniform. As many as eighty-seven blows, representing about 630 tons of steel, have been produced from one lining without any repairs whatever, except, after the fiftieth blow, new fireclay bricks to the nose. Thirty-seven more blows, equal to about 270 tons of steel, were converted in the same lining after renewing the front or blowing side and putting in a third fireclay nose. At the end of our last week's work (April 17th), during which bricks made of the best pot clay were used for this purpose, instead of being scoured away as had been invariably the case with the commoner ones, they were little the worse

for wear, and would, we feel sure, have run for a second week. The vessel bottoms (all made with a mixture of tar and lime rammed round pins) during this same week, averaged eight blows each, the maximum being twelve and the minimum four; but this bottom was taken out on completion of the week's work, and was very little worn. With respect to output, during the eight weeks ending April 17th (omitting Easter week, which was a broken one), 3380 tons of steel were made, or an average of 422 tons per week, the largest week being that ending March 27th, when 541 tons 7 cwt. were produced. In conclusion, we think it will be apparent to all that there are no difficulties in the working of the process. We are satisfied that as good steel can be produced by it from phosphoric pig, and quite as regularly as that obtained from hematite in the ordinary gannister-lined converter. We have shown that it is an easy matter to produce a malleable ingot iron, containing practically no carbon and very little manganese by this method, which, to say the least, it is rather difficult to do from hematite pig-iron by the old process; and although our only experiment (results of which we have laid before you) to produce a harder quality of steel from phosphoric pig high in manganese, without the addition of any manganiferous pig, at the end of the operation did not turn out as satisfactorily as we could have wished, there appears to us little doubt but that this too will be accomplished, as well as the production of soft steels, suitable for boilers and ships' plates, etc., in a similar manner. It is true that our production from one pair of converters has never yet exceeded 541 tons 7 cwt. in one week, but it must not be forgotten that the process is still a new one, and that the plant at our disposal is not of modern construction, nor well adapted to its requirements. These requirements are, in our opinion (on account of the lining), either additional fixed converters, or duplicates with proper facilities for changing, as well as suitable arrangements for the speedy removal of the large quantity of slag. Under these conditions, in a well-arranged shop, we feel sure that not only as great an output can be obtained by the process as is now being produced in the best English practice in the conversion of hematite, but also that it may be made to equal anything that has ever been accomplished by our friends on the other side of the Atlantic.

ON THE STEEL-COMPRESSING ARRANGEMENTS AT THE BARROW WORKS.

By Alfred Davis, of London.

Paper read before the Institution of Mechanical Engineers, at Barrow.

The unsoundness of steel castings, particularly in the case of ingots made by the Bessemer or Siemens-Martin process, has given manufacturers considerable trouble, and occasioned much waste of material.

A good deal has been stated and written of late as to the cause of this unsoundness, which occurs principally at the upper end of the ingot; but it appears now to be pretty generally conceded that the defects proceed from two distinct causes: First, the existence of gases, generated at the point of transition from the fluid to the solid state, which are imprisoned in the form of bubbles when the surrounding metal becomes solid; and secondly, the existence of spaces formed by the natural contraction of the metal in cooling, by reason of the outer skin first becoming solid, and refusing to follow up the interior portion of the ingot, which subsequently cools, and consequently occupies a smaller space.

Various systems, designed to cure this evil, have already been discussed before this Institution. The system of compressing fluid steel by the direct application of high pressure steam, has recently been adopted by the Barrow Hematite Steel Works, and by Messrs. Bolckow, Vaughan & Co., and has the merit of simplicity combined with efficiency. The arrangements adopted for the purpose are founded upon those used by Mr. H. R. Jones of the Edgar Thomson Steel Works at Pittsburgh, where the system has been used for some years.

A high pressure steam boiler is provided, and communicates with a receiver, which is attached to the side of the ingot crane, and which is furnished with a row of cocks corresponding with the number of ingot moulds. From these cocks strong india-rubber pipes convey the steam to the ingot moulds, which are arranged in the arc of a circle round the ladle crane. The metal from the ladle is poured through a loose pouring cup, which rests on a conical seat at the top of the ingot mould. As soon as the pouring is finished, this cup is removed, and a lid having the steam pipe ready coupled to it, is placed on the top of

the mould, and secured to it by a steel cover. The cock on the receiver is then opened and the steam allowed to act upon the metal until it has completely set. The result of this pressure is to make the ingot sensibly shorter than when cast in the ordinary manner, the difference, according to experiments made at the Edgar Thomson Works, being from $1\frac{1}{2}$ inch to 2 inches in a 5 feet or 6 feet ingot. The ingots when cold are perfectly level at the top, and there is no porous head requiring to be cut off.

The arrangements adopted by the Barrow Steel Company differ somewhat from those in operation at the Edgar Thomson Works. These arrangements require only a very brief explanation.

The ingot moulds, which are of similar construction to those used by the Edgar Thomson Company, are placed in a row, within a dock or siding, the centre line of which runs to the centre of the pit. The metal flows from the ladle into a trough mounted upon wheels and provided with runners at points corresponding with the centres of the ingot moulds when the trough is in position. This trough runs upon rails, placed on either side of the row of ingot moulds, and can readily be removed after the moulds are charged. Each mould is provided with a steam-tight cover, having a wrought-iron pipe attached to it, furnished with a stop-cock. This pipe communicates at right angles with the main steam pipe, which runs parallel with the side of the dock. The junction of the branch steam pipes with the main is formed by means of a cast-iron sleeve piece, with stuffing boxes, to enable the covers, with their respective cocks and pipes, to be thrown back out of the way when not in use.

The boiler for supplying the steam has been constructed by Messrs. Daniel Adamson & Co. It is 3 feet 6 inches in diameter and 9 feet high, and is intended to be worked at a pressure of 200 pounds per square inch.

At the Cambria Steel Works in Pennsylvania an attempt was made two or three years ago to inject water through the cover of the ingot mould after the metal had been poured. The heat of the molten steel of course generated steam, which acted as a compressing medium; a safety valve being provided and loaded to the pressure required. The disadvantages of this system, as compared with that now described, are sufficiently obvious; the complication of parts and the danger from explosions being very great.

The results obtained by the process of casting ingots under steam

compression are highly satisfactory. Not merely is the ingot perfectly sound, but the action of the steam is such as to enable the men to work it earlier and in a hotter state than with the ordinary method, so that there is an appreciable increase in the output. The presence of the steam also acts beneficially on the sides of the mould, and causes it to last longer.

The pressure necessary to produce a perfectly sound ingot will depend upon the quality of steel to which it is applied. At the Edgar Thomson Works it is found that for ordinary rail metal 100 pounds per square inch is sufficient. But for milder steel a higher pressure is needed; and since experience has proved that steam is readily dealt with at very high pressures, there does not appear to be any reason why 1000 pounds or 1500 pounds per square inch should not be applied if required. It is only a question of giving sufficient strength to those parts which are exposed to the pressure. As a matter of fact the boilers designed by Mr. Loftus Perkins will carry a steam pressure of 2000 pounds per square inch with perfect safety. The question of making tight joints between the ingot moulds and covers with such high pressure is one of considerable importance; but there are several ways in which this difficulty may be overcome. In using steam at a very high pressure, the size of the supply pipe may be considerably reduced, and the mode of attachment greatly simplified; and since the amount of steam used is inconsiderable, the size of the boiler would be correspondingly small. As an alternative, in cases where high pressures are needed for the consolidation of fluid metals, the author proposes the use of compressed air. With this system a pressure up to 1500 pounds or 2000 pounds per square inch may be obtained without danger or difficulty, as is completely demonstrated by the torpedo practice at Woolwich, and by the experiments carried out by Colonel Beaumont, in connection with the use of compressed air for tramway locomotion.

The advantages of an elastic compressing medium in the consolidation of fluid metals, as compared with the hydraulic process, scarcely need to be dwelt upon. In applying hydraulic pressure a rigid piston is necessary; and the outer portions of the cooling mass (which are the first to set) must be crushed down, before the interior portions, which are still liquid, are reached by the pressure. A considerable amount of power is wasted in consequence. In addition the fluid metal is forced against the sides of the mould, and in a contrary direc-

tion to that which it naturally follows in the operation of cooling. With steam or compressed air the operation is reversed; as soon as contraction commences the entire ingot is surrounded by a uniform pressure, which continually follows up the natural contraction of the mass.

In conclusion, the author would suggest that the principle of elastic pressure, in connection with the consolidation of fluid metals, although at present applied to Bessemer ingots only, is well worth the consideration of those interested in the manufacture of all kinds of steel and iron castings, and particularly of heavy guns.

The discussion on Mr. Davis' paper was opened by Mr. E. Windsor Richards, who referred to experiments which he had made at the Eston Works, and who showed photographs of ingots which had been planed down the middle to ascertain whether or not they were sound. In examining ingots it was, he maintained, necessary to plane them apart in this way in order to expose their soundness or unsoundness throughout their whole depth. Of the ingots shown in the photographs one had not been compressed, while No. 2 had been compressed with steam at a pressure of 80 pounds, and No. 3 with a pressure of 130 pounds. These sections showed a progressive improvement, but bubbles were still visible in No. 3, this showing that a still higher pressure of steam was desirable. To supply steam at this increased pressure a small vertical boiler has been constructed by Mr. Daniel Adamson for use at the Eston Works, while a similar boiler is being used at Barrow, it being worked at 200 pounds per square inch. With this pressure Mr. Richards hoped to get a perfectly solid ingot. Mr. Richards next dealt with the gases contained in the bubbles or honeycombs. It was the custom in former days, he remarked, for forge managers when anything went wrong to blame it to the presence of sulphur; in the same way it was now the fashion amongst steelmakers to attribute mishaps to carbonic oxide. Experiments which he had made, however, disposed of the theory that the gas enclosed in bubbles formed in an ingot contained only carbonic oxide, and showed that the gases really enclosed were chiefly hydrogen and nitrogen. To prove this fact he had had a tank made sufficiently large to contain an ingot, this tank having a stuffing box at the bottom through which a drill could be introduced. The ingot to be experimented with was placed in the tank, the latter being filled with water, and a hole $2\frac{1}{2}$ inches in

diameter was then drilled up 4½ inches into the bottom of the ingot. This drilling resulted in the release of gases, and the gases so evolved were collected and analyzed by Mr. Stead, of Middlesbrough, when the composition was found to be as follows: Hydrogen, 78·6 per cent.; nitrogen, 20·4 per cent.; carbonic acid, 0·2 per cent.; and carbonic oxide, 0·8 per cent. From the hole just mentioned, no less than 18 cubic inches of these mixed gases were obtained. Altogether he considered the process of compressing fluid steel was a most valuable and essential one. In answer to a question put by Mr. Cowper, he also stated that he considered the gases were, by the application of steam, expelled through the openings left at the bottom of the mould.

The next speaker was Dr. Siemens, who remarked that the benefits to be derived from the compression of fluid steel were well proved by the results obtained by Sir Joseph Whitworth. He (Dr. Siemens) had himself tried to compress fluid steel some time ago, but he had not succeeded in devising a simple means of carrying out the process. He was therefore much interested in the system of steam compressing when it was brought before the Iron and Steel Institute, and had offered to give facilities for its trial. He found, however, that with very mild steels the steam pressure available was too low to insure satisfactory results. Sir Joseph Whitworth employed a pressure of two tons per square inch. With mild steels they were much troubled with honeycombing near the surface of an ingot, and to remove such honeycombing a pressure of one to two tons per square inch appeared essential, although central cavities might be got rid of with moderate pressures. Where the gases went to during the process of compression was somewhat difficult to determine, but he believed that the gases were simply reduced in volume, and occluded. Referring next to the failure of the *Livadia's* boilers, Dr. Siemens stated that he had received samples of the steel, and had had it analyzed. Inasmuch, however, as the matter was put before him in a semi-official way, he did not feel at liberty at present to lay details of the analysis before the meeting. It was, however, especially desirable that the failure of the *Livadia's* boilers should not be regarded as impugning the character of good mild steel. A boiler made of such steel could not, he contended, burst under any circumstances, as the metal would stretch at the rivet holes, and the boiler would foul by leakage, the rivet holes being drawn oval. The experiments made by Mr. Deane, at Swindon, and described by Mr. Parker in a paper read before the Institute of Naval

Architects proved this, while Messrs. Eastons and Anderson had also tried unsuccessfully to burst a steel boiler made by them, this boiler being made red hot in a special furnace, and again tested after recaulking where necessary. Altogether, mild steel was the most trustworthy material known, and it might be punched, sheared, etc., without injury. The experience of the Admiralty with the steel used in the *Iris* and the *Mercury* showed this: this steel was supplied by works in which he was interested, and not a single plate or angle iron from these vessels having been returned to the makers. Since then the Admiralty had employed steel for both ships and boilers almost to the exclusion of wrought iron, about 10,000 tons having been supplied to them. The "demon of cheapness" was, however, abroad, and was exercising a most detrimental influence on steel plates. The works he had already alluded to were now making two qualities of steel plates, one being a cheap class of steel, while the others were of a special class of metal, the quality of which they guaranteed, and in the manufacture of which exceptional care was taken. Notwithstanding the advantage of this latter class of steel, many engineers preferred the cheaper variety even for boiler work, although if they were using iron they would pay for Lowmoor at a rate far higher than that of the best steel. Much of the rivet steel which is being sold is also far from being of the quality which was desirable, the rivet bars being in some cases rolled from scrap ends of steel of a quality by no means suitable. Taking these circumstances into account, it was not fair to criticise the behavior of any particular steel plate or bar without specifying the price paid for them.

The next speaker was Mr. Thomas Adams, who stated that he had been employed by the Board of Trade to carry out for them experiments on different samples of steel. The officials of the Board had previously made experiments at Liverpool, but had been unable to burst the vessels owing to leakage, the highest pressure they succeeded in attaining being 500 pounds per square inch. They then made trials at Glasgow, when they only succeeded in getting 480 pounds. Returning to Liverpool they again got 500 pounds, while at some railway works they got up to 750 pounds, and at London reached 1500 pounds per square inch, the latter pressure however, being unable to burst a $\frac{5}{16}$ inch plate. After these failures they went to Manchester and placed the matter in the hands of Mr. Adams, who succeeded, he stated, in making a vessel which stood 2000 pounds per square inch without

leaking, and which failed through the fracture of the plate. The testing vessel made by Mr. Adams consisted of a strong rectangular frame like the bottom ring of a locomotive firebox, this ring having a thick plate placed on one side of it, and the experimental plate on the other. To obtain tightness of joints two strands of twine were laid between the plates and frame inside the line of rivets, and two similar strands outside that line. Besides being secured to the frame around their circumference the plates were of course stayed together, great care being taken with the fit of these stays, and they being provided with nuts at the ends. With a test vessel so made Mr. Adams informed the meeting that the joints kept perfectly tight, and it was only necessary to employ a single plunger one inch in diameter by six inches stroke to carry out the hydraulic test. In reply to Mr. Crampton, Mr. Adams stated that he had not employed a cylindrical vessel, as the joints could not be kept tight.

Next, Mr. Snelus remarked that Mr. Richards was evidently not very positive as to what became of the gas when it disappeared under the application of pressure to fluid steel. He quite agreed with Mr. Richards that some delusion had prevailed as to the nature of the gases contained in the bubbles in an ingot, and this had in a great measure arisen from the conclusions experimentally arrived at by Sir Henry Bessemer, to the effect that an ingot during the process of setting gave off carbonic oxide. He (Mr. Snelus) had many years ago read a paper before the Iron and Steel Institute "On the Gases evolved during the Bessemer Process," and he then showed that during the earlier part of the blow there is discharged an excess of carbonic acid, but ultimately an excess of carbonic oxide. With regard to the occlusion of gases, palladium occludes about 700 times its volume of hydrogen, while molten silver occludes oxygen, to a remarkable extent, but gives it up during setting. Thus certain metals appear to have a special affinity for particular gases, and it was quite possible that steel might have such an affinity for carbonic oxide, this gas being occluded throughout the metal, while cavities were filled with hydrogen and nitrogen. Taking all these matters into account there was probably a mode of getting rid of the blowholes by chemical means instead of by compression, the idea being to mingle with the steel some body which occludes the gases which at present collect in bubbles. Altogether he did not believe that the gases were driven out by compression, but simply that the compression induced more powerful occlusion, this

practically being the theory which had been advanced by Professor Müller, of Osnabrück.

Mr. Hayes next suggested that probably the compression by the admission of steam might be more effectively performed if the steam were admitted at both ends, and Mr. Sharp stated that he had cast copper perfectly solid by employing a secret chemical means of preventing the formation of blowholes. It was then announced by Mr. Cowper that Mr. J. T. Smith had at his suggestion kindly made a small steam boiler, which it was intended to burst by hydraulic pressure at the steel works that afternoon.

The next speaker was Mr. Arthur Paget, who asked Mr. Davis if the process described in the paper had not some twelve months prior to its use in the United States, or in England, been described in a paper read before a scientific society in France, and also whether a similar process, but using air in place of steam, was not in use at the Bolton Iron and Steel Works. Mr. Paget further inquired whether there was really any advantage—as suggested in the paper—in employing an elastic compressing medium in place of a plunger. Next, Mr. R. E. Crompton directed attention to the proportions of hydrogen and nitrogen mentioned by Mr. Richards as existing in the honeycombs, and were they such as to suggest the formation of ammonia, which would of course be affected by the moisture in the steam. Mr. Crompton further mentioned the experiments of Edison as appearing to show that the entire removal of occluded gas from metals deprived them of their ductility. Mr. R. H. Tweddell next asked if Mr. Richards could give any data as to how the specific gravity of the steel was affected by the compression, but unfortunately this inquiry was not replied to.

Mr. Davis, in replying to the discussion, remarked that he considered that the photographs exhibited by Mr. Richards proved the value of the process he had described, while he believed that a pressure of 200 pounds per square inch would be found sufficient for dealing successfully with any class of steel. It was, however, most important to apply the pressure directly after pouring, and by means of the new appliances at the Barrow Works it had been rendered possible to apply the pressure in 13 seconds after teaming. He was quite aware of the French trials which had been made with this system of compressing by M. Considore, and he had inserted a paragraph concerning them in his paper, but it had been struck out. In reply to a letter on this

subject signed "Justice," which had appeared in *Engineering*, he had received a communication from Mr. Jones, of the Edgar Thomson Steel Works, in which he stated that he (Mr. Jones) had made his first experiments on the use of steam in this way in 1875. The fact was that the same idea had evidently occurred independently to Mr. Jones and Mr. Considere. Mr. Davis then proceeded to explain a variety of modes of fixing down the mould in which ingots were to be compressed, and he concluded by remarking that he was unaware of the use at Bolton of air under pressure for compressing fluid steel.

ON THE MANUFACTURE OF JUTE.

By William Fleming, of Barrow-in-Furness.

Paper read before the Institution of Mechanical Engineers, at Barrow.

While jute has long been known to the natives of Bengal, and largely used by them in various textile manufactures and for paper-making purposes, its introduction into England is of comparatively recent date.

In 1796 the East India Company imported some small quantities of jute, and afterwards continued importing it in small lots now and then, but it made no progress whatever with the manufacturers of this country. What was thus imported seems to have been employed in the neighborhood of London in the production of door mats, ropes, etc. Portions of the samples, however, appear to have found their way to Abingdon, in Oxfordshire, where there were a few manufacturers of sackings and woollen carpetings. There it was spun, by hand, and used up to a small extent in some of their fabrics. The Abingdon manufacturers therefore appear to have the credit of being the first to employ jute in textile fabrics in this country.

About 1833 some of the jute yarn thus spun at Abingdon was sent to Dundee, where the matter attracted attention, and shortly afterwards was commenced at Dundee that manufacture of jute, which has resulted in such an extraordinary development of this industry in Great Britain, Ireland and the Continent. The increase in the consumption of jute during the last fifty years is most remarkable. The total export of jute from Calcutta in 1829–30 amounted to 20 tons, valued at 60*l.*; it has now risen (in addition to the enormous consumption for manufac-

turing purposes in Bengal itself) to upwards of 350,000 tons, or nearly 2,000,000 bales annually, amounting in value to about 6,000,000*l.*

Jute is mainly grown in Bengal and exported from Calcutta. It is sown in March and April and during the following three months attains a height of from 10 to 12 feet, while the stems reach from one to two inches in circumference.

Shortly after the plant has flowered it is cut down near to the ground, tied up in bundles of from 50 to 100 plants each and "petted," that is, steeped in stagnant water from eight to ten days till the "bast" (or the fibre lying between the bark and the stem) can be separated from the wood. It is then removed from the water and beaten gently against a board until, with a little management, the native operator can strip off the whole from the stem without damage to either stem or fibre. The fibre is then drawn through the water until all impurities are washed or picked off. It is then dried in the sun, and, after having been assorted into different grades of quality, is exported, under various distinctive marks, in bales of 400 pounds each to London, Liverpool, Dundee, Barrow and other markets.

Softening.—The jute fibre being of a somewhat harsh nature, the first process which it has to undergo after being released from the bale, where it is very tightly compressed, is that of softening. This is done by dividing the jute into stricks or handfuls, and passing these stricks through between a series of heavy fluted rollers, which, by crimping and crushing, and in a manner rubbing the fibres, render them softer and more yielding.

The softening machine consists of four horizontal rows of fluted rollers about 9 inches in diameter and 2 feet 6 inches long, and ten rollers in each row. Each roller in the bottom or fourth row bears the weight of the three rollers above it, those in the third row are pressed by the weight of two rollers, and those in the second row by the weight of one roller. The stricks of jute pass first between the pairs of rollers constituting the first and second rows, then return between the second and third rows, and pass lastly between the third and fourth rows, being delivered in a softened condition at the opposite end of the machine to that where they were introduced, and having been subjected during the process to an increasing weight as they entered between the different rows. The softening of the jute is at the same time assisted by an operation called "batching," *i. e.*, the sprinkling of the stricks with oil and water whilst they are passing through the machine. This

is done by having two cisterns, one containing water and the other containing oil, placed over the machine. Inside the cisterns are revolving rollers which lift the liquids and discharge them over a scraper, or doctor, dropping them upon the jute as it passes between the rollers.

Breaker-Card.—The jute having been softened, and weighed into bundles, is conveyed to the breaker-card.

The principal parts of this machine consist of a cylinder 1 feet in diameter by 6 feet wide on its working surface, covered with sharp steel pins inclined slightly forward in the direction in which the cylinder revolves, and of a number of small rollers arranged round the periphery of the cylinder, each of these rollers being also covered with pointed pins. The stricks of jute are laid or spread by the attendant upon an endless traveling sheet, which conveys them to the first roller, called the feeder, and the pins which cover the surface of this roller enter the jute and carry it forward to the point where it comes in contact with the pins of the cylinder. The surface speed of the pins of the feeder being about 10 feet per minute, whilst the speed of the pins of the cylinder is about 2,000 feet per minute, the fibres, which are slowly presented and delivered by the feeder, receive a severe combing or dressing from the pins on the cylinder before they are finally released by the feeder. The cast-iron shell which encases the feeder for about one-sixth of its circumference serves to keep the fibres imbedded in the feeder-pins, so as to prevent their being carried off by the cylinder before being properly carded. A large quantity of the fibre, however, when struck by the pins of the rapidly revolving cylinder, is broken off and carried forward on the points of the cylinder pins, and it is to straighten out, comb and split these portions that the other rollers, called workers and strippers, are applied.

The first roller that acts, after the fibres have left the feed roller, is the worker. This roller, which is about 9 inches in diameter, is placed with its pin-points at a distance of from $\frac{1}{16}$ to $\frac{1}{8}$ inch from the points of the cylinder pins. The angle of the worker pins is very much more acute than that of the cylinder pins, and inclined in the opposite direction. The roller revolves in the same direction as the cylinder, but at a speed of only about 50 feet per minute. The effect is that the fibres projecting from the pins of the cylinder are caught on the pins of the slowly revolving worker, and as the direction and pull of the cylinder pins tend to force the fibres on to the pins of the worker, a

considerable portion is retained by the latter. The worker is in its turn cleared of fibre by the stripper, a roller about 13 inches in diameter, which revolves at a speed of about 430 feet per minute in the opposite direction to the worker, and, traveling with pins inclined forward, it strips the fibres from the worker and is afterwards itself cleared by the still more rapidly traveling cylinder.

The same process is repeated at the second worker and stripper, which are placed rather closer to the pins of the cylinder than the first two rollers. After passing the second worker and stripper, the fibres are carried forward to the doffer, a roller about 16 inches in diameter, which travels in the same direction and at about the same speed as the worker, and has its covering similarly arranged, except that in the doffer the pins are rather finer and more numerous. The pins of this roller are set close to those of the cylinder, so that the whole of the fibres are caught by them and carried round to the two doffing-rollers, which take the jute from the doffer in the form of a continuous broad sheet or fleece. This thin sheet of carded jute, after it issues from the doffing roller, is gathered together or contracted from about 5 feet to 4 inches by means of a tin conductor, and it then passes through the delivery-rollers in the form of a continuous sliver, and falls into a can.

The surface speed of the doffing and delivery-rollers is generally about fourteen times quicker than that of the feed-roller; consequently if the jute be spread so that the feed-roller receives about 2 pounds per yard, the sliver delivered into the can will measure about 7 yards per pound.

The tin rollers under the workers and strippers are to prevent the fibres, as much as possible, from falling to the ground when the stripper is clearing the worker.

Finisher-Card.—The jute sliver as delivered by the breaker card is not considered to be sufficiently carded for most purposes, and it is therefore necessary that the process of carding should be repeated on a second machine called the finisher-card. The principle on which this machine works is exactly the same as that of the breaker card, but instead of only two workers and two strippers there are sometimes three, four or five pairs of these rollers, and the pins on the surface of the cylinder and rollers are finer and set closer to one another, so as to comb and split the fibres more efficiently. The finisher-card is fed by slivers from twelve cans from the breaker card upon an endless traveling sheet, similar to that used in the breaker-card, which carries them

forward to be acted upon by the cylinder of the finisher in the same manner as the strieks of jute are acted upon in the breaker-card. It will be understood that the slivers as delivered by the breaker-card, although continuous, must necessarily be rather irregular, *i. e.*, thicker in some parts than others, but by putting twelve of these already partially carded slivers through the finisher together, a kind of average is struck and the slivers delivered by the finisher card are much more regular and even. The "draft," or proportion of speed between the delivery roller and feeder of the finisher-card is about 16 to 1, so that, being fed by twelve slivers, each measuring about 7 yards per pound, and these being subjected to draft of 16, the sliver delivered by the finisher-card will measure about 9¾ yards per pound.

Drawing-Frame.—The next process after carding is to have the fibres of jute drawn out straight and laid parallel alongside one another, and this is accomplished on a machine called the drawing-frame.

There are several kinds of drawing frame, all intended to produce the same results, but the kind most in use is the system called the "spiral gill drawing-frame." In this machine the slivers, which have been delivered into the cans from the finisher card, pass over a conductor plate and thence between three rollers, which are called the retaining-rollers, and are in fact the feed-rollers of the machine. Just in front of the delivery side of these rollers is a series of traveling bars on which are fixed hackles or gills, *i. e.*, brass stocks with steel pins standing upright in them. These bars, with the gills attached, travel forward from the retaining-rollers, carrying with them the jute fibres into which the pins penetrate, their speed being the same as that of the retaining-rollers, or just as much faster as will insure that the slivers are kept tight and do not rise off the pins. The bars are propelled by means of two longitudinal screws, one at each end of the bar, cut at a pitch varying from 1½ to 2 threads per inch. The end of the bar which enters into the thread of the screw is beveled to the angle of the thread, so that the body of the bar and the pins are quite vertical, whilst the end fits the spiral, and there being one bar in each thread of the screw, when the screws revolve the bars glide forward, supported on steel slides. These screws are called the top screws, and the length of their threaded part is made suitable for the length of fibre, say about 10 or 11 inches for carded jute. As each bar arrives at the front or further end of the top screws it drops from the slide

which has been supporting it in position into the threads of two bottom screws placed exactly under the top screws, cut to the same hand, but revolving in a contrary direction. These bottom screws accordingly carry back the bar, supported on bottom slides, and with its pins still upright, to the other end of the frame, where the thread of each screw is terminated by a projecting cam, by which the bar is lifted up into the top screw again, close to the retaining roller, causing the pins of the gills to penetrate the sliver which the retaining roller is delivering. Thus a continuous forward travel of bars is maintained for 10 or 11 inches in length in front of the retaining rollers, moving at what is practically the same speed.

At the front or delivering end of the screws, where the bar drops out of the sliver, are the drawing-roller and the pressing-roller above it, the former being made of steel, about $2\frac{1}{2}$ inches in diameter, and the latter generally of cast-iron covered with leather about 8 inches in diameter. These rollers, which are pressed together by means of weighted levers, move at a speed about six or seven times greater than the retaining-rollers or gills; consequently the fibres, when delivered by the gills as the traveling bars drop from the top to the bottom screws, are seized between the rollers and drawn away from the pins of the gills, which act as a kind of comb, holding them back and insuring that they do not enter the bite of the rollers in a crossed or tangled state.

The length of each traveling bar is about 3 feet, and there are fixed on it four gills, each 6 inches wide on the pins. Each set of bars and gills, with its retaining and drawing-rollers, conductors, etc., constitutes what is called a carriage; and drawing-frames are made with one, two, three, four or five carriages. Thus a drawing-frame of two carriages, and four gills per carriage, will have eight sets of gills, and as two slivers from the finisher-card are supplied to each gill, the number of cans at the back of the machine will be sixteen. Assuming the speed of the drawing-roller to be six times that of the retaining or feeding-rollers and gills, it is evident that the sliver delivered by the drawing-roller will be six times longer than when it enters the machine, and as there are two card-slivers to each gill, and each card-sliver may be assumed to measure $9\frac{1}{2}$ yards per pound, the sliver coming from between the drawing and pressing-rollers will measure about 28 yards per pound. But, for the purpose of completing the process of straightening the fibres and laying them parallel, as well as more

effectually equalizing the slivers, it is necessary to put the jute through a second drawing-frame, and, therefore, it is more convenient to unite the slivers from two gills upon a doubling-plate arranged for the purpose in front of the drawing-roller, and so to deliver the sliver from all the eight gills comprised in the two carriages through four pairs of rollers, called delivery-rollers, into four cans; the sliver in each can will consequently measure about 14 yards per pound.

The second drawing-frame is constructed in an exactly similar manner to the first drawing-frame, except that the pins in the gills are rather finer and ranged closer together, and instead of the slivers from two gills being united together in front of the drawing-roller, the slivers from each gill are carried straight from the drawing to the delivery-rollers and run into the can, thus making eight deliveries from the machine. As there are two slivers, each of 14 yards per pound, put up to each gill, the sliver as delivered into the can from this second drawing-frame, if the draft on the machine is six, will measure 42 yards per pound.

Roving-Frame.—The next machine in the system of preparing machinery is the roving-frame. The object of this machine is to draw out still further the fibres in the jute sliver and wind them on bobbins in a form convenient for the final process of spinning into yarn. The manner of drawing out the slivers is exactly the same as that employed in the drawing-frames, but as only one sliver is put up to each gill in the roving-frame, and that sliver measures about 42 yards per pound, narrower and smaller gills serve the purpose, and eight gills can be fixed on each bar instead of four, and in consequence of the slivers being so much lighter, the pins of the gills are finer and set closer together. The draft of the roving-frame is usually about seven, so that the sliver delivered by the drawing-roller of the roving-frames will measure about 294 yards per pound.

This is too thin a sliver to deliver into a can, and for that reason, and also for general convenience, the sliver is twisted slightly and wound on to a bobbin; in this form it is called "rove." In order to twist the sliver into rove and wind it on to the bobbin, there are employed a spindle and flyer, constructed on the same principle as in similar machines for cotton and other fibres, but for jute the parts are larger and stronger. The number of spindles in a jute roving-frame may vary from twenty-four to sixty-four; a very usual number to put in is fifty-six, and as there must be a gill for each spindle and flyer, seven

carriages with eight gills on each bar are necessary to supply fifty-six spindles. The spindles with their flyers stand vertically in two rows in front of the drawing-rollers and revolve at a speed of about 600 revolutions per minute. Inside the flyer, and turning freely on the spindle, is placed the bobbin which is to receive the rove. This bobbin is driven by gearing independently of the spindle and flyer, but revolves in the same direction. The amount of twist given to the rove should be only just sufficient to give it strength to unwind from the bobbin, in the subsequent process, without allowing the fibres to separate. Now, suppose the suitable twist for rove to be one turn per inch of sliver delivered; then the speed of the drawing-roller must be arranged so as to deliver one inch for each revolution of the flyer, and the speed of the bobbin must be calculated to be just sufficiently behind that of the flyer to take up the quantity delivered by the drawing-rollers. For instance, the spindle and flyer make 600 revolutions per minute, the roller delivers 600 inches per minute, and the circumference of the bobbin shank is 5 inches, the speed of the bobbin will have to be 480 revolutions per minute, or 120 less than the flyer, because by lagging behind to that extent the bobbin will wind up 120 laps, each 5 inches long, or 600 inches per minute. But, as the bobbin fills, the diameter on which it winds continually increases, and the speed must be diminished accordingly. Thus, when the bobbin is nearly full, its circumference will be 15 inches, or three times what it was at starting; consequently the bobbin will have to run only 40 revolutions per minute behind the flyer in order to wind the rove with one twist per inch. In order to wind the rove regularly from top to bottom of the bobbins, the rail on which these are carried is made to rise and fall, so that the bobbin moves up and down inside the legs of the flyer, and the diminution in speed of the bobbin is caused by a projection attached to the lifting-rail being arranged to release a catch each time that the rail arrives at top and bottom of its traverse. The regulating motion is obtained from a bowl or pulley with a leather face, which is made to revolve by contact between two flat circular iron discs rotating in contrary directions. Each time that a catch is released either at top or bottom of traverse, the bowl is allowed to slide a little nearer to the centre of the two discs, whereby its speed is diminished, and in this way the speed of the bobbin is also reduced for each successive lap that is laid on.

As already explained, the jute fibres in this slightly twisted form

are termed "rove." But for the heavier classes of yarn (say when 1 pound measures less than 400 yards), it is very usual to make the "yarn" on the roving-frame. To do this it is only necessary to increase the twist sufficiently to give proper strength to the yarn.

Spinning-Frame.—The object of this machine, which completes the first stage in jute manufacturing, is to reduce the rove which comes from the previous machine to the required size and then to twist the fibres together so as to form what is known as "yarn."

The number of spindles in a spinning-frame varies according to circumstances, but for an average class of jute yarns, a very usual number is sixty-four on a side, arranged in one row, at a pitch or distance from one another of 3¾ inches. The main parts of the machine are: the rack or creel for the bobbins containing the rove, the retaining-rollers, the binding-plate, conductor, drawing-rollers, thread-plate, spindle and flyer and bobbins to receive the yarn. The bobbins containing the rove are placed on pins fixed on the rack, and the rove is introduced through a conducting-plate between two fluted rollers pressed together, which form the retaining rollers; then over the binding-plate and through a narrow conductor into the bite of the drawing-roller and pressing-roller, the former being made of iron and the latter of wood and pressed against the drawing-roller by means of steel springs. The drawing and pressing-rollers run at a surface speed considerably in excess of the retaining-rollers, the difference being regulated by change-wheels to suit the size of yarn required. We will assume the drawing-roller to be moving seven times faster than the retaining-roller, so as to give a draft of seven. The slight twist which the rove has received in the roving-frame gives it sufficient consistency to hold together and pull the bobbin round on its pin, so as to supply the retaining-rollers, but when gripped at one end between the retaining-roller and its pressing-roller, and at the other end between the drawing and pressing-rollers, the latter pair moving at the quicker speed, the slight twist which the fibres have received does not prevent them from parting. Not being supported by gills, as in the drawing and roving-frames, the rove is made to press against the binding-plate in order to retain the twist, and so prevent the fibres from separating too easily and from passing through the drawing and pressing-rollers in an irregular manner.

By the draft of seven, the rove is elongated from 294 yards per pound as it enters the retaining-rollers to 2058 yards per pound when

it passes from the drawing-roller. The fibres are twisted by the spindle and flyer in the same manner as in the roving-frame, but the amount of twist given to the yarn is very much greater than that given to the rove, and the bobbin is not, as in the roving-frame, driven by wheels, but is dragged round after the flyer by the thread and is retarded by friction sufficiently to wind on the yarn, the friction being regulated by the attendant to suit the strength of the yarn.

In illustrating the action of these different machines, a certain weight of jute has been assumed to be laid on the feed-sheet of the breaker-card with certain drafts and doublings in the separate subsequent machine; the result of which would be to produce yarn known as "7 pound," because each "spindle," or length of 14,400 yards, would weigh 7 pounds, but by varying the weight, drafts or doublings other sizes of yarn are produced. The finest yarns in jute, made from the best qualities, are about $1\frac{3}{4}$ pounds to 2 pounds per spindle, or say about $\frac{1}{4}$ pound per mile, whilst from the coarsest class yarn is made of which a mile will weigh more than 30 pounds.

The yarns, having been prepared in the necessary forms for the looms, are woven into fabrics of great variety, suitable for the requirements of every market in the world, and these fabrics undergo various processes of calendering, mangling and finishing.

Jute is the cheapest fibre known, and hence the very general demand for jute fabrics in every country. Jute manufactures are now almost entirely used for the conveyance of grain, flour, rice, linseed, coffee, pepper, saltpetre, etc., as also for guano and all chemical manures, while in the export of the raw materials, cotton and wool, nothing else is now employed for packing. All makers of textile goods now use jute hessians and baggings for the packing of their manufactures.

The finer qualities of jute yarns are woven into fabrics suitable for the production of curtain cloths, tapestries, etc.; for furniture purposes (such as the "Kalameit," now produced in the Barrow Flax and Jute Works) and for carpets, rugs, etc. They are also used largely, in combination with cotton, silk and woolen yarns, in the weaving of numerous ornamental goods. In fact, the list of the varied purposes to which jute, jute yarns and jute fabrics are now extensively applied is curious and remarkable, embracing, as it does, telegraph cables, wire ropes, oilcloth and linoleum manufactures, ropes, twines, cords, etc., even down to artificial hair.

The cuttings (or the few inches of hard fibre cut from the bottom of

the plant in India) are now largely used by the paper-makers in this country, as well as in India, America and the Continent, and the wastes made in the general manufacture of jute, which cannot be spun over again, come into value in connection with paper-making, felt-making and other purposes.

This enormous and general demand has brought about a more than equivalent producing power in this country, in India and elsewhere, and during the past few years the jute trade has been suffering from the effects of this over-production, but as the requirements of the world are increasing so rapidly, the improved demand must soon rectify this unfortunate state of things.

DIRECT MEASUREMENT OF THE INTERNAL RESISTANCE OF MAGNETO-ELECTRIC MACHINES IN MOTION.

By TH. DU MONCEL.

In a series of articles Mr. G. Cabanellas has recapitulated the means that can be employed to investigate in an easy manner the best method of working, and the current yielded by magneto-electric machines, and to allow of their being classified in the order of their merit.

One of the greatest difficulties he has encountered has been the determination of the internal resistance of the generators, with the values that result from effects produced inside the generator while in motion, and which play an important part in the formulæ deducted from the laws of Ohm and Joule. It has been known for a long time, from the researches of Le Roux, Jamin and Roger, that the resistances determined from the application of Ohm's formulæ to the conditions in the experiment do not correspond at all to the real resistance of the generator in repose, and that the latter should be augmented in a large proportion. (See the "Exposé des applications de l'électricité" of M. du Moncel, vol. ii, p. 271.)

It is then necessary to determine these resistances directly, so as to be able to state precisely what causes are in operation, and from them to deduct practical conclusions, and it is this which Mr. G. Cabanellas has just done in his first work which he has submitted to the Academy of Sciences. The difficulty was to avoid the induction produced by various causes which develop electro motive forces in the wire of the

ring, rendering it impossible to measure by the Wheatstone Bridge method. The most important of these accidental inductions is that which results from the action of terrestrial magnetism, which is capable by itself alone of generating currents relatively energetic, as was shown by the experiments of M. Lami. To remove this, M. Cabanellas has opposed to one another the effects produced by it on two similar Gramme rings, moving in the same conditions, and in this manner he could determine without the intervention of that cause of disturbance the measure of the resistance of the double ring, submitted to a movement of rotation. Whether the ring was moving or in repose M. Cabanellas could make it the fourth side of a Wheatstone Bridge, and in consequence he could measure the resistance in both cases. The following are the results which he has obtained:

The resistance of the moving ring, with respect to that of the same ring maintained in a fixed position and for a mean rate of rotation of 450 turns per minute, showed an increase of about 25 per cent. (the temperature of the two rings being the same), and this increase was not at all modified by the intervention of metallic resistance introduced between the two connected rings, or outside of them. The variations produced in the electro-motive force of the generator (within the limits which allow the use of the Bridge of the Siemens Universal Galvanometer) appear to have no more influence on the measurements whether the rings were in motion or repose, and the influence of weights applied to the collectors of the rings produced differences only of a secondary order. With powerful electro-motive forces, it has been the same, but M. Cabanellas has employed for verification an arrangement of two galvanometers, one of low resistance placed in the circuit, and one of great resistance placed in a shunt, which has enabled him to obtain direct measurements, without necessitating the use of standard resistances specially made of large wire. The resistance of each ring was then given by the proportion $\frac{E}{Q\,I}$.

It would have been interesting to study the manner by which the increase of resistance varies with the speed of rotation of the rings, so as to fix the laws of the phenomena, but the experiments made at the establishment of Messrs. Sautter, Lemonnier & Co. required such great derangements of the business that M. Cabanellas, not willing to abuse good nature, has postponed the further experiments which he intends to make.—*La Lumière Electrique.*

THE THEORY OF THE TELEPHONE.

Our readers will remember that in 1879 M. Ader constructed a telephone without a diaphram, the sound being given out by a soft iron wire enclosed in a helix, through which the current passed. The action was explained by du Moncel as due to longitudinal vibrations in the wire resulting from successive lengthenings and shortenings of the wire under the action of the magnetizing helix, it being well known that an iron core is lengthened by magnetization. M. du Moncel employed this fact to support his molecular theory of the action of the Bell telephone. Since that time M. Boudet, of Paris, has, by means of his sensitive microphone, succeeded in revealing these changes of length. Moreover, M. Ader himself has investigated the subject very closely, and besides measuring the effect in question has arrived at the important principle that *all bars of magnetic nature submitted to a mechanical action, be it compression, torsion or tension, tend to recover their primitive molecular arrangement under the influence of the current which magnetizes them.*

The apparatus employed by M. Ader in his experiments consists of a small straight electro-magnet, having its core formed of an iron wire 0·04 or 0·05 metres long, and one extremity chamfered off. Upon this chamfer acts a long lever, which serves the double purpose of an indicator and exciter of the mechanical action. The lever terminates in an index which moves itself before a graduated scale (in front of which is a lens) and is connected to the magnetic core in a manner differing with the mechanical action to which the latter is submitted.

In the cases where compression and tension are produced two distinct effects are seen. On allowing the current to flow for several instants continuously the index is gently displaced, moving up the scale in the former case (compression) and down the scale in the latter case (tension), with a deflection proportional to the intensity of the battery and the time of the closure of the current. This effect is evidently due to the dilation of the core in each case under the influence of the heat developed by the current, for it is obtained with a core of copper. On closing the circuit momentarily the lever rises instantly in both cases, and instantly falls on the current being interrupted. At the same time a "dry" sound can be perceived at each make and break of the cur-

rent when the ear is applied against the table supporting the apparatus. But the apparatus is so arranged that the displacements indicated in the two cases correspond to two mechanical effects diametrically opposite in character—that is to say, to a lengthening and shortening of the core. It can, therefore, only be due to a molecular action tending to annul the mechanical strain on the core in either case.

In the case of torsion, the index rises always at the moment of making the circuit and falls again at the moment of breaking it, and in a degree corresponding to the force of the mechanical action, as can be determined by a weight sliding on the torsion lever. In this case the thermal effect is not shown at all, since the indicating lever does not change its position by reason of the lengthening or shortening of the magnetic needle. The magnetization in this case tends, as in the experiments of MM. Guillemin and Coulon, to untwist the wire.

The length by which the core is shortened by closing the circuit momentarily by the current, according to M. Ader's calculation, is less than one ten-millionth of a metre, or one ten-thousandth of a millimetre. It is greater under the influence of torsion, and less under the influence of tension.—*The Electrician.*

Mechanical Theory of Heat.—In Jacob Hermann's *Phoronomia sive de Viribus et Motibus Corporum solidorum et fluidorum, libri duo*, 1716, sections 658 and 659 treat of the internal movement of fluids and of heat as dependent upon molecular motion. The latter section contains a demonstration of the theorem that "heat, other things being equal, is in a ratio compounded of the density of the heated body and of the duplicate ratio of the disturbance of each one of its particles. *Ann. d. Phys. u. Chem.* C.

Occlusion of Gases in Aluminium and Magnesium.—M. Dumas finds that not only iron and silver possess the property of retaining large amounts of gas for an indefinite period, but that aluminium and magnesium also have the same property. For equal weights magnesium contains a volume twice as great as aluminium. But magnesium is so much lighter than aluminium that it will hold only one and a half times its own volume. Silver seems to prefer oxygen; aluminium and magnesium hydrogen, each metal appearing to have its individual preference.—*Comptes Rendus.* C.

New Magnetical Experiments.—M. Ader has performed some interesting experiments upon bodies which are slightly magnetic. He finds that elder pith is more sensitive than ordinary wood, paper, etc. With a Jamin magnet, sustaining a weight of 100 k. (220·46 lbs.), and provided with two small polar armatures, separated by an interval of 2 mm. (·78 in.), he has been able to attract, at a distance of 3 mm. (·118 in.), a pith ball of 5 mm. (02 in.), suspended by a thread. He has been able even to raise it, and when once attached to the magnet considerable force is necessary in order to remove it.—*Comptes Rendus.* C.

Discovery of a New Elementary Body in the Lava of Vesuvius.—Prof. Scacchi, the celebrated mineralogist and crystallographer, in studying the yellow incrustation which is found on certain portions of the Vesuvian lava ejected in 1631, and which he calls Vesbine, has discovered a body which differs in its character from all the known elements. He considers Vesbine as a vesbiate of alumina, and he regards vesbic acid as the oxacid of a new element, *vesbium*, which, according to the properties of its compounds, will probably stand between molybdenum and vanadium. Stas thinks that vesbium may be found in some of the common ores, where its presence has never been suspected because it has been confounded with some of the known acidifiable metals.—*Bull. de l'Acad. Belg.* C.

Influence of Light, Copse and Mould on Forest Growth.—M. Gurnaud has conducted a series of observations, during the past nineteen years, upon the solid contents of annual growth in a forest among the Jura mountains. He finds that: 1. Light, when it strikes the ground without having been sifted by foliage, stimulates the production of carbonic acid in the decompositions which are engendered by the humus, together with a decomposition of the same gas by the chlorophyll. 2. The growth of wood diminishes when the underbrush intercepts, to any great extent, the access of light to the soil and diminishes its reflex action on the branches of the trees. 3. This interruption of reflex action is due mainly to the spread of the underbrush, for when it is kept trimmed the vertical shoots which are retained interpose no obstacle. 4. The mould, under too great a thickness, loses a part of its virtue, and, like barn-yard manure which is too deeply buried, remains inert for many years.—*Comptes Rendus.* C.

Bronzing Liquid.—Dissolve 10 parts aniline red and 5 parts aniline purple in 100 parts of 95 per cent. alcohol, in a water-bath; then add 5 parts benzoic acid, and heat the mixture until the greenish color changes to a light bronze-brown. This liquid, when brushed upon metal, leather or wood, produces a beautiful bronze effect.—*Bayer. Ind. u. Gewerbeblatt.* C.

Precaution against Fire-damp.—The connection of mining explosions with low barometric pressures has long been noticed. In the colliery of Seraing barometers have been lately placed near each of the ventilators, with directions to give the ventilating fans 75 turns per minute in fine weather, 80 turns in changeable weather, and 85 turns in stormy weather.—*L'Echo Indust.* C.

Alcohol in Animal Tissues.—M. J. Bechamp finds that alcohol may be detected in a large variety of animal tissues, even during life, as well as after death, in such quantities as to throw great doubt upon the evidences of alcoholic poisoning which have hitherto been regarded as conclusive. While agreeing with Pasteur, in most of his views as to the nature of ferments, he thinks that the bacteria which appear in the putrefaction or other alterations of animal tissues do not come from atmospheric germs, and he recounts a number of experiments which seem to confirm his views.—*Am. de Chim. et de Phys.* C.

Utility of Solar Boilers.—M. Abel Pifre describes a variety of modifications of Mouchot's apparatus, adapted both to domestic and to industrial use. He thinks that they are of especial importance in connection with the projected railway to Central Africa. The Barbary figs, which are very abundant, yield about 25 per cent. of alcohol, more than the sugar beets. A single solar boiler, with a reflector of five metres diameter, can distil, without cost for fuel, 200 litres (52·8 gal.) of this alcohol per day, the raw material costing nothing, and the refuse being valuable for the food of cattle. The importance of this result becomes evident upon considering that Algiers imports every year more than 30,000 hectolitres (792,500 gals.) of alcohol, and that it will need to import still more for the manufacture of its wines, which require the addition of alcohol in order to bear transportation. Pifre is now experimenting upon the conversion of solar heat into electricity, and of the electricity into mechanical work, by the intervention of a Gramme machine.—*Mem. de la Soc. des Ing. Civ.* C.

Phosphorescent Lighting. — Dr. Phipson takes sulphide of barium, or some other substance which is rendered phosphorescent by the solar rays, and encloses it in a Geissler tube, through which he passes a constant electric current of a feeble but regular intensity. He claims to obtain in this manner a uniform and agreeable light, at a cost lower than that of gas. — *Les Mondes.* C.

Transparent Gold.—If a solution of gold in aqua regia is neutralized by carbonate of soda, and a solution of oxalic acid is added, the gold is precipitated in a brilliant yellow powder. On examining this precipitate by the microscope the flakes are found to have a triangular or hexagonal form and to be translucent, the color of the transmitted light depending on the thickness of the crystals. — *Les Mondes.* C.

Transplanting Eels.—The French engineering corps has been experimenting for some years past upon the transport of young eels by railway, in order to supply various streams in the different departments. Very little care is necessary except to avoid shipment when the temperature descends below the freezing point. They have already successfully transplanted about 1,500,000 eels. — *Ann. des Ponts et Chaus.* C.

Planetary Arrangement.—In recent papers before the French Academy MM. Gaussin, Faye, Chase and Schötel have discussed various indications of law in the arrangement of the planets and some of their bearings upon the nebular hypotheses of Laplace and Hershel. The indications which were given by Prof. Chase were the closest and most striking, furnishing numerical evidence of a projectile force connecting the solar system with the fixed stars.—*Comptes Rendus.* C.

Influence of Light on Size of Leaves.– M. Ch. Flahault, in the *Annales des Sciences*, brings forward additional observations to support his view that under equal conditions the leaves of plants of the same species are larger in proportion as we go nothward, these relatively higher dimensions being due to the duration of light of relatively feeble intensity. In cases where the chlorophyll is formed in the absence of light, it must be formed at the expense of the materials stored up in the tissues. The importance of these reservoirs of nutriment is still greater in the case of flowers. Thus, of hyacinths, both red and blue, M. Flahault found no difference in the color of the flowers grown in the light or in the dark, the color being manufactured from the stores of material in the bulbs.

New Welding Process.—Krupp has recently taken out a German patent for a new process of welding tubes and tires. He draws the tube on a pair of ordinary rolls and heats the whole length of the portions which are to be welded in a portable fire-box, into which air is blown so that the heat is directed against the weld. After the necessary heat is obtained the rolls are set in motion and the place which is to be welded is repeatedly drawn through them.—*L'Ingen. Univ.* C.

Accuracy of Glass Gauge-tubes.—In his experiments upon compressibility Amagat employs for manometers glass tubes of about 1 mm. (0·4 in.) internal diameter, and 10 to 12 mm. (·39 to ·47 in.) exterior diameter. He has subjected them to severe and repeated tests, and finds that they undergo no change, either in diameter or in length. Those which he has employed for more than a year, under powerful and prolonged pressures, give the same results to-day as when he gauged them for the first time.—*Comptes Rendus.* C.

Stability of Bramante's proposed Cupola for St. Peter's.—M. Alfred Durand-Claye has examined, both theoretically and experimentally, the strength of the cupola which Bramante projected for the church of St. Peter in Rome. He finds that it would have been stable with materials which would resist a pressure of eight kilogrammes per square centimetre (113·8 lbs. per sq. in.). It is interesting to find that modern scientific methods thus confirm the inspirations of a skillful architect whose numerous domes were projected by feeling rather than by mathematical knowledge.—*Bull. de la Soc. d'Encour.* C.

Profit of Public Works.—M. de Labry has written an essay, in which he discusses the various advantages of public improvements to invested capital, to adjacent regions, and to the government, showing that the dividends to stockholders and the direct revenues of government constitute only a small portion of the benefits conferred by increased facilities for travel and the transportation of merchandise. He thinks that both self-interest and duty should prompt the inhabitants of regions which have been well developed to contribute towards the opening of new districts. Even if the contributions appear to be sunk, the increase of trade and of general prosperity will, almost without exception, amply repay all the outlay.—*Ann. des Ponts et Chauss.* C.

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MOTION OF VISCOUS FLUIDS.

By Dr. THOMAS CRAIG.

United States Coast and Geodetic Survey.

In a paper read before the American Association for the Advancement of Science, at its recent meeting in Boston, I mentioned some results which I had obtained in the course of an investigation of the motion of viscous incompressible fluids. It was not possible on that occasion to give in detail the analytical processes which were employed in making the necessary reductions and transformations; so the present paper has been prepared for the purpose of giving the results mentioned before the Association, and also the methods of arriving at them. The equations of motion of a viscous incompressible fluid are

$$\begin{aligned} \rho \frac{Du}{Dt} &= \rho X - \frac{dp}{dx} + \mu \nabla^2 u, \\ \rho \frac{Dv}{Dt} &= \rho Y - \frac{dp}{dy} + \mu \nabla^2 v, \\ \rho \frac{Dw}{Dt} &= \rho Z - \frac{dp}{dz} + \mu \nabla^2 w, \end{aligned} \tag{1}$$

where u, v, w denote the component velocities of a particle at the point

x, y, z, p the pressure at that point, μ the coefficient of viscosity, ρ the constant density of the fluid and X, Y, Z external forces. The operator $\frac{D}{Dt}$ of course indicates total differentiation with respect to the time. To these is to be added the equation

$$\frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz} = o \tag{2}$$

expressing the continuity of the fluid. On account of the viscosity of the fluid the motion will be in part rotational; designating by ξ, η, ζ the components of angular velocity at the point x, y, z, these quantities are defined by the equations

$$\begin{aligned} \xi &= \tfrac{1}{2}\left(\frac{dw}{dy} - \frac{dv}{dz}\right), \\ \eta &= \tfrac{1}{2}\left(\frac{du}{dz} - \frac{\partial w}{dx}\right), \\ \zeta &= \tfrac{1}{2}\left(\frac{dv}{dx} - \frac{du}{dy}\right). \end{aligned} \tag{3}$$

The following relations, which are readily deduced from these, are frequently of value:

$$\begin{aligned} \Delta^2 u &= 2\left(\frac{d\eta}{dz} - \frac{d\zeta}{dy}\right), \\ \Delta^2 v &= 2\left(\frac{d\zeta}{dx} - \frac{d\xi}{dz}\right), \\ \Delta^2 w &= 2\left(\frac{d\xi}{dy} - \frac{dy}{dx}\right). \end{aligned} \tag{4}$$

Denote by Ω the resultant angular velocity; then

$$\Omega^2 = \xi^2 + \eta^2 + \zeta^2; \tag{5}$$

Also write

$$2\,q = u^2 + v^2 + w^2. \tag{6}$$

Performing the differentiations necessary to determine the form of $\Delta^2 q$, we readily find for this quantity the expression

$$\begin{aligned} \Delta^2 q = u\,\Delta^2 u + v\,\Delta^2 v + w\Delta^2 w &+ \left(\frac{du}{dx}\right)^2 + \left(\frac{du}{dy}\right)^2 + \left(\frac{du}{dz}\right)^2 \\ &+ \left(\frac{dv}{dx}\right)^2 + \left(\frac{dv}{dy}\right)^2 + \left(\frac{dv}{dz}\right)^2 \\ &+ \left(\frac{dw}{dx}\right)^2 + \left(\frac{dw}{dy}\right)^2 + \left(\frac{dw}{dz}\right)^2, \end{aligned} \tag{7}$$

which, as we shall presently see, can be written in a much briefer form. Write for brevity

$$\begin{aligned} a &= \frac{du}{dx}, & f &= \tfrac{1}{2}\left(\frac{dv}{dy} + \frac{dw}{dz}\right), \\ b &= \frac{dv}{dy}, & g &= \tfrac{1}{2}\left(\frac{du}{dz} + \frac{dw}{dx}\right), \\ c &= \frac{dw}{dz}, & h &= \tfrac{1}{2}\left(\frac{dv}{dx} + \frac{du}{dy}\right). \end{aligned} \tag{8}$$

The internal friction involves a certain dissipation of energy; the function expressing the rate of dissipation per unit volume has been called by Lord Rayleigh the "dissipation-function"; denoting this quantity by E, we have

$$E = 2\mu\,(a^2+b^2+c^2+2f^2+2g^2+2h^2). \tag{9}$$

In order to obtain the rate of dissipation of energy throughout the entire space filled by the fluid it will be necessary to perform the integration

$$\iiint E\,dx\,dy\,dz$$

throughout that region.

Equations (3), (5), (7) and (8) now give

$$u\,\nabla^2 u + v\,\nabla^2 v + w\,\nabla^2 w = \nabla^2 q - \frac{1}{2}\,\mu\,E - 2\Omega^2 \tag{10}$$

or

$$E = 2\mu\left\{\nabla^2 q - (u\,\nabla^2 u + v\,\nabla^2 v + w\,\nabla^2 w) - 4\Omega^2\right\} \tag{11}$$

If we suppose that the forces X, Y, Z possess a potential, we may write

$$X = -\frac{dV}{dx}, \quad Y = -\frac{dV}{dy}, \quad Z = -\frac{dV}{dz};$$

furthermore, it is easily seen that

$$\frac{Du}{Dt} = \frac{du}{dt} + u\frac{du}{dx} + v\frac{dv}{dx} + w\frac{dw}{dx} + 2(w\eta - v\zeta), \text{ etc.}$$

Making these substitutions in equations (1) and they become

$$\begin{aligned}
\frac{du}{dt} + \frac{d(V+q)}{dx} + \frac{1}{\rho}\frac{dp}{dx} + 2(w\eta - v\zeta) &= \frac{\mu}{\rho}\nabla^2 u,\\
\frac{dv}{dt} + \frac{d(V+q)}{dy} + \frac{1}{\rho}\frac{dp}{dy} + 2(u\zeta - w\xi) &= \frac{\mu}{\rho}\nabla^2 v, \qquad (12)\\
\frac{dw}{dt} + \frac{d(V+q)}{dz} + \frac{1}{\rho}\frac{dp}{dz} + 2(v\xi - u\eta) &= \frac{\mu}{\rho}\nabla^2 w.
\end{aligned}$$

In the case of steady motion the first term in the left hand member of each of these equations vanishes, and for this case we have as the differential equations of motion

$$\begin{aligned}
\frac{dP}{dx} + 2(w\eta - v\zeta) &= k\nabla^2 u,\\
\frac{dP}{dy} + 2(u\xi - w\xi) &= k\nabla^2 v, \qquad (13)\\
\frac{dP}{dz} + 2(v\xi - u\eta) &= k\nabla^2 w,
\end{aligned}$$

when k (the kinematic coefficient of viscosity) $= \frac{\mu}{\rho}$ and

$$P = V + q + \int\frac{dp}{\rho}.$$

If we assume that the quantities $\nabla^2 u$, $\nabla^2 v$, $\nabla^2 w$ are the first differential coefficients with respect to x, y and z of a function, Q, these equations become

$$\begin{aligned}
\frac{d(P - kQ)}{dx} &= -2(w\eta - v\zeta),\\
\frac{d(P - kQ)}{dy} &= -2(u\zeta - w\xi), \qquad (14)\\
\frac{d(P - kQ)}{dz} &= -2(v\zeta - u\eta).
\end{aligned}$$

Multiplying these by u, v, w, respectively, and then by ξ, η, ζ, and adding in each case, we have, writing for brevity $\theta = P - kQ$,

$$\begin{aligned}
u\frac{d\theta}{dx} + v\frac{d\theta}{dy} + w\frac{d\theta}{dz} &= 0,\\
\xi\frac{d\theta}{dx} + \eta\frac{d\theta}{dy} + \zeta\frac{d\theta}{dz} &= 0. \qquad (15)
\end{aligned}$$

and also

$$\frac{d\theta}{du} = q'\,\Omega\sin.\,\theta, \qquad (16)$$

where q', $= \sqrt{2q}$, is the current velocity and θ is the angle between the stream-line and the vortex-line at the point x, y, z.

Hence the conditions that the state of motion of the fluid for which

$$\int^2 u.\, dx + \int^2 v.\, dy + \int^2 w.\, dz$$

is an exact differential shall be a state of steady motion are as follows. It must be possible to draw in the fluid a system of surfaces, $\theta =$ const., infinite in number, and each of which is covered by a network of stream-lines and vortex-lines. This is the property indicated by equations (15). The product

$$q'\, \Omega \sin.\, \theta\, dn$$

must be constant over each such surface, dn denoting the length of the normal drawn to a consecutive surface of the system. In his work on Fluid Motion Professor Lamb gives results in the case of perfect fluids which are identical in form with these. The conditions to be satisfied in order that

$$\int^2 u.\, dx + \int^2 v.\, dy + \int^2 w.\, dz$$

shall be an exact differential are obviously

$$\left.\begin{aligned} \int^2 \xi &= o. \\ \int^2 \eta &= o. \\ \int^2 \zeta &= o. \end{aligned}\right\} \qquad (17)$$

These conditions may also be arrived in a different way from equations (14); the quantity

$$(w\eta - v\zeta)\, dx + (u\zeta - w\xi)\, dy + (v\xi - u\eta)\, dz$$

must be an exact differential; the conditions for this are

$$\left.\begin{aligned} u\frac{d\xi}{dx} + v\frac{d\xi}{dy} + w\frac{d\xi}{dz} &= \xi\frac{du}{dx} + \eta\frac{du}{dy} + \zeta\frac{du}{dz} \\ u\frac{d\eta}{dx} + v\frac{d\eta}{dy} + w\frac{d\eta}{dz} &= \xi\frac{dv}{dx} + \eta\frac{dv}{dy} + \zeta\frac{dv}{dz} \\ u\frac{d\zeta}{dx} + v\frac{d\zeta}{dy} + w\frac{d\zeta}{dz} &= \xi\frac{dw}{dx} + \eta\frac{dw}{dy} + \zeta\frac{dw}{dz} \end{aligned}\right\} \qquad (18)$$

The equations of vortex motion in a viscous fluid are, however, known to be

$$\frac{d\xi}{dt} + u\frac{d\xi}{dx} + v\frac{d\xi}{dy} + w\frac{d\xi}{dz} = \xi\frac{du}{dx} + \zeta\frac{du}{dy} + \eta\frac{du}{dz} + k\int^2\xi$$

with two similar ones. Making in these $\frac{d\xi}{dt} = \frac{d\eta}{dt} = \frac{d\xi}{dt} = o$, we have as the necessary conditions for the existence of equations (18) since k cannot vanish,

$$\nabla^2 \xi = \nabla^2 \eta = \nabla^2 \zeta = o.$$

From equations (13) we have in every case

$$o = u\left(\frac{dP}{dx} - k\nabla^2 u\right) + v\left(\frac{dP}{dx} - k\nabla^2 v\right) + w\left(\frac{dP}{dx} - k\nabla^2 w\right),$$
$$o = \xi\left(\frac{dP}{dx} - k\nabla^2 u\right) + \eta\left(\frac{dP}{dx} - k\nabla^2 v\right) + \zeta\left(\frac{dP}{dx} - k\nabla^2 w\right). \tag{19}$$

so that the same conditions for steady motion hold now as in the particular case just mentioned; the surfaces in the fluid are, however, given by the differential equation

$$dP - k\,(\nabla^2 u.\,dx + \nabla^2 v.\,dy + \nabla^2 w.\,dz) = o. \tag{20}$$

In this general case the quantities in parentheses in the left hand members of equations (13) are not the first differential coefficients of a function x, y, z, but in equations (14) we may write

$$\begin{aligned} 2\,(w\eta - v\zeta) &= -\frac{d\Psi}{dx}, \\ 2\,(u\zeta - w\xi) &= -\frac{d\Psi}{dy}, \\ 2\,(v\xi - u\eta) &= -\frac{d\Psi}{dz}; \end{aligned} \tag{21}$$

and since by taking the equation of continuity into account we have

$$\nabla^2 Q = o, \tag{22}$$

equations (44) give

$$\nabla^2 (P - \Psi) = o. \tag{23}$$

Any solution of (22) giving Q as a function of x, y, z will enable us to determine u, v, w by means of the equations

$$\nabla^2 u = \frac{dQ}{dx}, \quad \nabla^2 v = \frac{dQ}{dy}, \quad \nabla^2 w = \frac{dQ}{dz}.$$

Writing

$$r^2 = (x - x')^2 + (y - y')^2 + (z - z')^2$$

we have

$$\begin{aligned} u &= -\frac{1}{2\pi}\iiint \frac{dQ}{dx'}\,\frac{dx'\,dy'\,dz'}{r}, \\ v &= -\frac{1}{2\pi}\iiint \frac{dQ}{dy'}\,\frac{dx'\,dy'\,dz'}{r}, \\ w &= -\frac{1}{2\pi}\iiint \frac{dQ}{dz'}\,\frac{dx'\,dy'\,dz'}{r}. \end{aligned} \tag{25}$$

The values of ξ, η, ζ obtained from these will necessarily satisfy the equation of condition

$$\nabla^2 \xi = \nabla^2 \eta = \nabla^2 \zeta = o.$$

A value for p can also be obtained from (33), but for the present we will leave this part of the subject and consider the more general case where the function Q does not exist. Write for convenience

$$\begin{aligned} A &= v\zeta - w\eta, \\ B &= w\xi - u\zeta, \\ C &= u\eta - v\xi. \end{aligned}$$

Equations (13) now become

$$\begin{aligned} \frac{dP}{dx} - 2A &= k\nabla^2 u \\ \frac{dP}{dy} - 2B &= k\nabla^2 v \\ \frac{dP}{dz} - 2C &= k\nabla^2 w \end{aligned} \tag{27}$$

And from these we have

$$\nabla^2 P = 2\left(\frac{dA}{dx} + \frac{dB}{dy} + \frac{dC}{dz}\right) \tag{28}$$

It is easy to see that an equation of precisely the same form will hold in the case where the motion is not supposed to be steady; for if we differentials equations (12) for x, y, z respectively and add the terms containing the differential coefficients of u, v, w with respect to t will disappear by virtue of the equation of continuity. Integrating (28) and remembering that

$$P = V + q + \int^{p} \frac{dp}{\rho}$$

We have, since ρ is constant

$$\frac{p}{\rho} + G - \left\{ \tfrac{1}{2}\pi \int\int\int \left(\frac{dA}{dx'} + \frac{dB}{dy'} + \frac{dC}{dz'}\right) dx'\, dy'\, dz' + V + q \right\} \tag{29}$$

In the general case G is a function of the time for steady motion, however, it is a constant. This expression for p can be transformed into another, the form of which is rather striking. Let

$$\begin{aligned} A &= \alpha D \\ B &= \beta D \\ C &= \gamma D \end{aligned} \tag{30}$$

Then α, β, γ are the direction cosines of a vector D whose components are A, B, C. Substituting in the equation

$$D^2 = A^2 + B^2 + C^2$$

the values of A, B, C, we have readily

$$D = q'\Omega\left\{1 - \left(\frac{u\xi}{q'\Omega} + \frac{v\eta}{q'\Omega} + \frac{w\zeta}{q'\Omega}\right)^2\right\} \tag{31}$$

Or, $$D = q'\Omega \sin.\ \varphi \tag{32}$$

Where φ is the angle between the stream-line and vortex-line at the point $x\ y\ z$. Now, supposing the fluid to be contained within a rigid (or non-rigid) closed surface; let a, b, c be the direction-cosines of a normal to this surface, then

$$a\alpha + b\beta + c\gamma$$

is the sine of the angle between plane containing the instantaneous axis of rotation Ω and direction of resultant velocity q', or

$$\sin.\ \varphi = a\alpha + b\beta + c\gamma \tag{33}$$

Similarly, if we denote by a', b', c' the direction-cosines of the line joining $x\ y\ z$ to $x'\ y'\ z'$ and ρ the angle between this line and the above mentioned plane we have

$$\sin.\ \varphi' = a'\alpha + b'\beta + c'\gamma \tag{34}$$

Take now the triple integral on the right hand side of (29)

$$-\frac{1}{2\pi}\int\int\int\left(\frac{dA}{dx'} + \frac{dB}{dy'} + \frac{dC}{dz'}\right)\frac{dx'\,dy'\,dz'}{r}$$

This is

$$= \frac{1}{2\pi}\int\int\int(aA + bB + cC)\ \frac{d\sigma}{r} + \frac{1}{2\pi}\int\int\int(a\,A + bB + cC)\ \frac{x'\ y'\ z'}{r^2}$$

Where $d\sigma$ is an element of the bounding surface. By virtue of (30), (32), (33), (34), we have now

$$-\frac{1}{2\pi}\int\int\int\left(\frac{dA}{dx'} + \frac{dB}{dy'} + \frac{dC}{dz'}\right)\frac{dx'\,dy'\,dz'}{r} \tag{35}$$

$$= \int\int\frac{q'\tilde{\omega} \sin.\ \theta \sin.\ \varphi}{r}\,d\sigma + \frac{1}{2\pi}\int\int\int\frac{q'\Omega \sin.\ \theta \sin.\ \varphi'}{r^2}\,dx'dy'dz'$$

And finally

$$\frac{p}{\rho} = G - (V + q) + \frac{1}{2\pi}\left\{\int\int \frac{q'\Omega \sin.\theta \sin.\varphi}{r}\, d\sigma + \right.$$
$$\left.\int\int\int \frac{q'\Omega \sin.\theta \sin.\varphi'}{r^2}\, dx'\, dy'\, dz'\right\} \quad (36)$$

If the motion in the fluid is a screw motion *i. e.*, if the direction of motion be along the instantaneous axis of rotation we shall have $\theta = o$, and consequently

$$\frac{p}{\rho} = G - (V + q) \quad (37)$$

If the plane containing the direction of motion and instantaneous axis of rotation be always normal to the surface we shall have $\varphi = o$ and then

$$\frac{p}{\rho} = G - (V + q) + \frac{1}{2\pi}\int\int\int \frac{q'\pi' \sin.\theta \sin.\varphi d}{r^2}\, dx'\, dy'\, dz' ; \quad (38)$$

and when x, y, z and x' y' z' lie in this plane

$$\frac{p}{\rho} = G\ (V + q) \quad (39)$$

In an article in the *Mathematische Annalen*, entitled "Einige Betrachtungen über die Gleichungen der Hydrodynamik," by D. Bobylew, the author studies the problem of vortex motion in viscous fluids by means of an arbitrary system of curvilinear coordinates. Among other results he arrives at that expressed by equation (36), viz., that the pressure is not an explicit function of the coefficient of viscosity. The form which he obtains for the pressure (*Math. Annalen*, Vol. vi, page 84) is identical with that given in (25). Another problem discussed by Bobylew (pages 82 and 83, *ibid.*) is the rate of variation of the kinetic energy of the fluid, but he only gives the value of this quantity for two particular cases. The coordinates chosen by Bobylew affords a noble opportunity for algebraical gymnastics, but they unfortunately give results of so complicated a character that they are not of much practical value. The following method for finding the rate of variation of the kinetic energy is at least simple and, as an investigation in rectangular co-ordinates, I believe it to be new, Bobylew's article being the only one I know of which touches on this subject. If we call K the kinetic energy we have, since q is half the square of the velocity,

$$K = \int\int\int q\rho\, dx\, dy\, dz \quad (40)$$

And
$$\frac{dK}{dt} = \rho \iiint \frac{dq}{dx} dx\, dy\, dz \tag{41}$$

the integration being, of course, extended throughout all the space occupied by the fluid. Take now equations (1) and multiply them by $u\ v\ w$ respectively and add, substituting for X, Y, Z their values as differential coefficients of V, and also write

$$V + p = -J; \tag{42}$$

This gives

$$\frac{dq}{dt} = u\frac{dJ}{dx} + v\frac{dJ}{dy} + w\frac{dJ}{dz} + \frac{\mu}{\rho}(u\nabla^2 u + v\nabla^2 + w\nabla^2 w). \tag{43}$$

By virtue of the equation of continuity the first three terms on the right hand side of this equation can be placed in the form

$$\frac{d(uJ)}{dx} + \frac{d(vJ)}{dy} + \frac{d(wJ)}{dz}.$$

Integrating this expression throughout the space filled by the fluid we have

$$\iiint \left(\frac{d(uJ)}{dx} + \frac{d(vJ)}{dy} + \frac{d(wJ)}{dz}\right) dx\, dy\, dz = \iint J(au + bv + cw)\, d\sigma \tag{44}$$

$a\ b\ c$ being the direction cosines of the normal to the bounding surface; if this surface be supposed rigid we have

$$au + bv + cw = o \tag{45}$$

and this integral therefore vanishes. Reverting now to equation (10) we have at once

$$\frac{dK}{dt} = \mu \iiint (\nabla^2 q - 2\Omega^2)\, dx\, dy\, dz - \tfrac{1}{2}\iiint E\, dx\, dy\, dz \tag{46}$$

This can only vanish on the supposition that μ and E are both zero, which can only be the case when the fluid is perfect. In making these quantities equal to zero we have

$$K = \text{Const.}$$

which is Helmholtz's theorem for perfect fluids. The integral

$$\iiint E\, dx\, dy\, dz$$

is as we know the total rate of dissipation of energy throughout the

entire fluid mass. We can give $\frac{dK}{dt}$ in another form by using the quantities A, B, C; for

$$-\left(\frac{dA}{dx}+\frac{dB}{dy}+\frac{dC}{dz}\right)=u\left(\frac{d\eta}{dz}-\frac{d\zeta}{dy}\right)+v\left(\frac{d\zeta}{dx}-\frac{d\xi}{dz}\right)$$
$$+w\left(\frac{d\xi}{dy}-\frac{d\eta}{dx}\right)+\xi\left(\frac{dw}{dy}-\frac{dv}{dz}\right)+\eta\left(\frac{du}{dz}-\frac{dw}{dx}\right)+\zeta\left(\frac{dv}{dx}-\frac{du}{dy}\right)$$
$$=\frac{1}{2}\left(u\nabla^2 u+v\nabla^2 v+w\nabla^2 w\right)+2\Omega^2 \qquad (47)$$

Therefore,

$$u\nabla^2 u+v\nabla^2 v+w\nabla^2 w=-2\left(\frac{dA}{dx}+\frac{dB}{dy}+\frac{dC}{dz}\right)-4\Omega^2, \qquad (48)$$

and

$$\frac{dK}{dt}=4\mu\iiint\Omega^2 dx\,dy\,dz-2\mu$$
$$\iiint\left(\frac{dA}{dx}+\frac{dB}{dy}+\frac{dC}{dz}\right)dx\,dy\,dz; \qquad (49)$$

but we have already reduced the second of these integrals and know that

$$\iiint\left(\frac{dA}{dx}+\frac{dB}{dy}+\frac{dC}{dz}\right)dx\,dy\,dz$$
$$\iint q'\Omega\sin.\,\theta\sin.\,\varphi\,d\sigma \qquad (50)$$

Consequently

$$\frac{dK}{dt}=4\mu\iiint\Omega^2\,dx\,dy\,dz-2\mu\iint q'\Omega\sin.\,\theta\sin.\,\varphi\,d\sigma \qquad (51)$$

Comparison of (46) and (61) gives at once

$$\iiint E\,dx\,dy\,dz=4\mu\iint q'\Omega\sin.\,\theta\sin.\,\varphi\,d\sigma$$
$$+4\mu\iiint\Omega^2 dx\,dy\,dz+2\mu\iiint\nabla^2 q\,dx\,dy\,dz \qquad (52)$$

For $\theta=o$ or when the direction of motion is along the instantaneous axis of rotation we have

$$\frac{dK}{dt}=-4\mu\iiint\Omega^2 dx\,dy\,dz$$
$$\iiint E\,dx\,dy\,dz=4\mu\iiint\Omega^2 dx\,dy\,dz+2\mu\iiint\nabla^2 q\,dx\,dy\,dz \qquad (53)$$

The same forms are obtained when $\varphi=o$, or when the plane containing the direction of motion and the instantaneous axis of rotation is normal to the surface.

Washington, D.C., Sept. 9th, 1880.

THE STEAM YACHT "ANTHRACITE" AND THE PERKINS SYSTEM OF HIGH PRESSURE STEAM.

By Major George Deane.

The little steam yacht *Anthracite*, which has lately visited this continent from England, being the smallest steamer that has ever performed the voyage under steam, crossed the Atlantic from shore to shore in 18 days, on a consumption of 19 tons of coal.

This event has naturally created a great deal of interest with the public generally, as well as with scientific engineers. At the request of friends in Philadelphia, I send the following brief description of the yacht and her machinery to the Committee on Publication of the Journal of the Franklin Institute:

The yacht *Anthracite* was built especially to demonstrate the capabilities of the Perkins system of using steam at higher pressures on an Atlantic voyage, and the more conspicuously to prove the economy of the system it was considered desirable that her tonnage should be as small as possible compatible with the safety of the crew, to which consideration all others had to give place. Her builders, Messrs. Schlesinger & Davis, of Wallsend, Newcastle-on-Tyne, England, were desired to take the New York pilot boats as a guide in laying down the lines for this yacht, and to rig her as a two-masted schooner. Her dimensions are as follows, viz.: Length, 84′ 6″; beam, 16′ 1″; depth, 10′ 2″. The engine and boiler rooms occupy 22′ 6″, and were so constructed to give plenty of space to those interested in watching the working of the machinery, the engine room being furnished with a comfortable settee for the use of those so occupied. Her gross tonnage is 70·26 and registered tonnage 27·91. She has bunkers to carry 16½ tons of coal, and a water tank in the engine room to contain 280 gallons of water. Her crew consists of twelve hands, all told, viz., one captain, one mate, two engineers, two firemen, one steward and cook, and five deck hands. Altogether, she is as well found, handy and safe a sea boat as could be built, and Captain Dent and all her crew speak in the highest terms of her behavior during the very rough and trying weather she had to encounter on her voyage to these shores, as unexpected at the season when she crossed as were the twenty ice-

bergs which were counted from her deck at one and the same time, being, as Captain Dent stated, "the grandest sight of the kind he had ever seen," and he is an old salt and well acquainted with these regions.

The engines of the *Anthracite*, built by Messrs. Hawks, Crawshay & Sons, of Gateshead-upon-Tyne, are constructed on the Perkins system of using steam at higher pressures, and have three cylinders, of 8″, 16″ and 23″ diameter, respectively, with a 15″ stroke. The high pressure and medium cylinders, placed one over the other, are single acting and worked by the same piston rod, the low pressure being double acting. The steam, which first enters the top of the high pressure cylinder, passes into the bottom of the medium cylinder and from thence to the low, is expanded thirty-two times, and is cut off at $\frac{1}{8}$ stroke in the high pressure cylinder and at $\frac{1}{4}$ stroke in the low pressure cylinder. The piston rods are packed with rings made of the Perkins patent metal, requiring no lubrication other than the steam, which it perfectly retains, and thus enables the cylinders to be covered over with a double casing of sheet iron, filled in with a non-conducting material, and so prevents loss of heat.

The Perkins boiler is constructed of a number of wrought iron tubes, which are welded at the ends and placed horizontally over each other, these tubes being connected by smaller tubes. The following are the particulars and dimensions of the boiler of the *Anthracite*: The fire-box is formed of seven rings of tubes. Over the fire-box there are fourteen sections of tubes, each section containing ten tubes, and each tube being 4′ 7″ in length. The internal diameter of these tubes is 2¼″ and the external 3″, so that they have a thickness of $\frac{3}{8}$ of an inch, the bursting pressure of which is 20,000 pounds to the square inch. Each section of this boiler was proved to 4000 pounds pressure on the square inch, and the boiler when built up complete was proved to 2500 pounds pressure on the square inch, and this is the test to which all boilers built on the Perkins system are put prior to use, so that such an event as a boiler bursting is next to impossible. The area of the fire-grate is 15 square feet and the total heating surface 633 square feet. The boiler of the *Anthracite* when filled contains about 90 gallons of water. It has been worked at a pressure of 700 pounds to the square inch by the British Admiralty, but the usual pressure employed is from 300 to 500 pounds, and the average pres-

sure being about 350 pounds to the square inch. The boiler is also covered in with a double casing of sheet iron, filled in with a non-conducting material to retain the heat as much as possible, and it was found during a trial test of this machinery lately carried out in England, that a thermometer placed against the boiler casing when the pressure averaged over 350 pounds indicated only 150° Fahr.

As distilled fresh water is used in the boiler the condenser is so constructed that no admixture between the fresh water used in the boiler and the salt water employed in condensing can take place. The distilled water is thus used over and over again, and could all joints and connections be made as practically tight, as they should be theoretically, there would be no loss of water from the escape of steam, etc. As it is, a certain small loss does take place, and this is made good from the tank of fresh water in the engine room, which is distilled before passing into the boiler. All impurities are thus excluded from the water before it enters the boiler, and by the use of the Perkins patent metal for packing the piston rods no lubricant is required in the cylinders, and thus all grease and acids are prevented from coming into contact with the water and so entering the boiler. By this means, also, the preservation and life of the boiler is very much lengthened, and it has been found that the tubes in a boiler which had been at work for fourteen years, when cut open by the English Admiralty, were in as good preservation as when first put to use. Another advantage, especially to yachting men, is that by using this metal the disagreeable smell of burning tallow is got rid of. The metal is made of a compound of tin and copper, and was discovered by Mr. Perkins after many years of experiments with various metals for packing his cylinders so as to effectually retain steam at higher pressures, and is sufficiently hard and flexible to perform the duty required in the cylinders without any other lubricant than the steam, and it has been found that where this metal is used the cylinders and rings get to be as smooth and bright as the face of a looking-glass, thus reducing the friction to a minimum.

Previously to the *Anthracite* leaving England her machinery underwent a trial test, of twelve hours' duration, "of the most rigorous description," by the eminent engineer, Mr. F. J. Bramwell, assisted by the well-known engineer, Mr. Rich, of Eastons & Anderson, and two other engineers. Mr. Bramwell, in his report of this trial, states

"that before comparisons can be properly instituted between the economy of the engines of the *Anthracite* and that of engines of different construction, these engines of different construction should be tried with the same rigor as has characterized the trial of the *Anthracite*." His report contains 128 diagrams, taken during the trial, besides other data, and he gives the consumption of fuel as 1·7 pounds per horse-power per hour for the continuous run, and 1·83 pounds per horse-power per hour *including the coal used in getting up steam*. The report also contains many other points and much information favorable to the Perkins system.

Since the arrival of the *Anthracite* in this country she has been examined and inspected by many of the leading engineers, shipowners, manufacturers, etc., etc., in America, who have taken advantage of the various opportunities given them of observing the working of the machinery during many short trips made for their convenience while the yacht was lying off New York, Philadelphia, Providence, Newport and Watch Hill, Stonington.

Latterly, at the request of the United States Naval authorities, she was for about a fortnight in the hands of the engineers of the Navy Yard at Brooklyn, where a Board of Officers, under Chief Engineer C. H. Loring, U.S.N., and appointed by Mr. Shock, Chief of the Engineering Bureau at Washington, opened up and examined her machinery, and were very much pleased with the appearance of the cylinders and rings after the Atlantic voyage. They also carried out a series of tests and experiments as to the capabilities of the boiler and engines, the consumption of water and coal, etc., etc., taking during the trials about 300 diagrams and other data. To work up all this data and prepare a report will of course take time.

The *Anthracite* has now returned to England, starting from Philadelphia.

It has taken many years to bring the system to its present state of perfection; in fact, it may be said to have taken three generations to do so; for Mr. Jacob Perkins, the grandfather of the present Mr. Loftus Perkins, was working with high pressure steam when he left this country in years gone by to establish a manufactory in England, and to introduce his steam gun, etc. At the present time the system, after many vicissitudes, like most great inventions, is gradually demanding more attention and gaining favor. Also, the good and

economical results obtained from the twenty odd engines now at work on sea and land in the old country prove that it cannot be long before the great economy resulting from thus using high pressure steam will be an acknowledged fact, appealing in the strongest possible manner to the interests of all; for the impossibility of danger arising from the bursting of the boiler will appeal to the interests of the public generally, and the economy of fuel to users of steam.

The voyage of the *Anthracite* to this country, I think, demonstrates fully that the system is quite adapted for use on an Atlantic or other voyage, under any circumstances, for the little steamer got a greater knocking about than would a larger vessel under similar circumstances.

And as to the economy of fuel, Mr. Bramwell's report, and the voyage of the *Anthracite* across from shore to shore in 18 days, burning only 19 tons of coal, and other evidence of the economy of engines working on this system, on land and sea, in England—all point to this claim to economy of fuel and space as a subject well worthy the consideration and inquiry of all manufacturers and shipowners, to whom the expenditure on account of fuel is becoming each day of more and more importance, and the space occupied by such extra fuel of more and more value to the shipowners, meaning as it does the carrying of more paying freight, instead of freight paid for, and to be a charge against the fair profits of the ship.

A matter of great consideration, and which cannot be overlooked in these days of close competition, is the cost of manufacturing the machinery for using steam on the Perkins system; but this is a matter that will soon find a solution among manufacturing engineers, some of whom are already quite prepared to execute any orders that may be given them for the Perkins High Pressure Engine and Boiler on as favorable terms as now demanded for the present engine and boiler. For the rest, supply and demand will rule the question of cost.

There is claimed for this system: 1st, small consumption of fuel; 2d, safety from explosion; 3d, durability of boilers; 4th, disuse of lubricants; 5th, reduction in weight and space—any one of which is an important consideration to steam users.

COAL GAS ENGINEERING.

By Robt. Briggs, C. E.

At the recent meeting of the British Association of Gas Managers a paper* was presented by Mr. T. Travers, of Cork, upon thermal effect of coal gas when employed in heating or cooking, from which the following is extracted. Mr. Travers gives the result of a number of tests made in "a plain, practical method, such as may be applied to the doings of every-day life," that is, tests made without the attempt to obtain exact experimental results, but merely to exhibit the probable heat effect of coal gas for domestic purposes. His preliminary tests were upon the evaporating effect of coal gas of various qualities by means of an apparatus which we are left to suppose was similar to a gas cooking stove, with no attempt to utilize the entire heat of the gases of combustion, which may be assumed to have been allowed to escape in the open air, in the usual way, without condensation of the vapor of water generated by the burning of the hydrogen of the coal gas. "The apparatus employed for producing coal gas was capable of carbonizing 30 cwt. of coal per day," which may be set down as producing 15,000 cubic feet of gas in that time. He consequently had distinctive specimens of gas to test, and Scotch cannel, Newcastle and South Wales coal was experimented with, giving the following results:

Coal.	Illuminating power.	Specific gravity.	Gas consumed in evaporating one imp. gallon of 10 lbs.	Heat used per cu. ft. of gas.
Cannel, . .	24 candles	.....	18·50 cu. ft.	522
" . .	22	.....	19·75	490
" . .	20	.....	20·50	471
Newcastle, .	16·5	.....	21·75	444
" . .	14·5	0·420	22·00	439
" .	13·5	.....	22·50	427
South Wales, .	10·5	.....	28·00	345
South Wales and 20 p. ct. cannel,	14	.....	23·50	411

* Report of meeting of British Association of Gas Managers, June 8th, 1880 the London *Journal of Gas Lighting*.

In the JOURNAL OF THE FRANKLIN INSTITUTE for April, 1878, will be found a paper by the collator of this article, computing the results of combustion of coal gas,* wherein it was shown that the theoretic heat effect of coal gas of specific gravity = 0·426 was, closely, 622 units where the vapor of water formed in the combustion was permitted to escape uncondensed. [It may be added here that when the vapor is condensed to water at 70° Fahr. the total heat units from 100 pounds of gas coal of the specific gravity of 0·426 are 2,154,350 units, while those from one cubic foot of coal gas at 70° are 690 units, with close approximation.] It follows that about 0·7 of the total heat effect possible (at 622 units) was utilized by Mr. Travers' arrangement from Newcastle coal gas of 0·420 specific gravity.

It will be noticed also that, with the same method of testing, the heat effect increased in some measure with the illuminating power. As the illuminating power increases or diminishes with the quantity of carbon present in "illuminants," and also as the specific gravity, this change can be attributed to the superior ultimate intensity of the carbon flame as compared with the hydrogen flame, an intensity nearly as 3 to 2 in favor of carbon (18293° to 12764°).

Besides these practical tests of different qualities of coal gas, Mr. Travers further instituted a comparison of results from such burners as are found in gas stoves in general, using Newcastle gas coal of 16 candles, as a standard of average gas at present supplied, in all the tests.

	Thermal Units per Cubic Foot of Gas.
No. 1.—Cooking stove fitted with a Bunsen burner formed by a ring of 1¼-inch wrought iron pipe with jet holes 1 inch apart gave .	244
No. 2.—Boiling stove, consisting of single burner, 9 inches diameter, made of ¾-inch pipe, jets ¾ inch apart, . . .	260
No. 3.—Hot-plate, consisting of three rings, each 6 inches diameter, jets ½ inch apart, .	280
No. 4.—Like the above, rings 4 inches diameter, .	310
No. 5.—Cooker, formed of bars of 1-inch wrought iron pipe, jets ½ inch apart, . .	338

* Further extended in the JOURNAL, *vide* April, 1878; June, 1878; Feb., 1879.

	Thermal Units per Cubic Foot of Gas
No. 6.—Concentric burner, consisting of a double row of rings, one inside the other, 6 inches diameter, ...	390
No. 7.—Burner, same construction as above, but 4 inches diameter, . . .	408
No. 8.—Solid flame burner, . . .	450
No. 9.—Wallace's burner adapted for domestic purposes, ...	580

The Wallace burner, here referred to, is constructed so that gas jets escape across an aperture like an atomizer, and the mixture of gas and air is more intimately effected than with the other burners.

It being almost certain that in all these instances the combustion was perfect, as the offensive nature of incompletely consumed gas is at once observable, it can be said, on the whole, these tests exhibit the improper control of air supply, or inadequate surface of the vessel receiving heat, or the incomplete contact with that surface, conditions within the province of the gas stove makers to regulate, whence the best ultimate effect to be anticipated from gas stoves is from 0·7 to 0·8 of the theoretic effect —say from 435 to 500 units of heat per cubic foot of gas.

The ordinary economy of coal as fuel in a kitchen range may be taken at 5000 units, the remainder of the heat escaping up the chimney, whence a cubic foot of gas is of equal value to about one-twelfth to one-tenth of a pound of coal. Unfortunately for the coal exhibit in this statement, not one-tenth of the heat given out in the range-fire in any one day is expended in cooking, and it is only in the faculty of warming the room and for heating water that coal demonstrates its economy over coal gas as a fuel.

The foregoing assumption as to comparative value of coal and gas as fuel can be reduced to dollars and cents as follows:

2240 pounds of anthracite coal, at 5000 units = 11,200,000 units, present value $6.00.

3000 cubic feet of gas, at 470 units = 1,410,000 units, present value $6.00.

Ratio of heat value of anthracite coal to that of city coal gas = 7 to 1.

Mr. Travers further describes his experience with burning lumi-

nous flames in the production of heat, giving as an instance the case wherein a stove "from one of the best makers was placed in a low-lying district, and the day pressure was not sufficient, with the result that the Bunsen burner, which formed the heating ring of the stove, frequently fired back." "To increase the pressure was out of the question, and to meet the case, the flame was converted from a non-luminous to a luminous one, of course effectually avoiding the risk of firing back. The consumption of gas was not increased by the alteration, for much of the heat that was before lost by convertion is now converted into radiant heat. Bunsen burners, to be used for heat-giving in fire-places are [says Mr. Travers] to my mind, and for the reasons above given, a mistake; for, unless special arrangements are made, over ninety per cent. passes off in the shape of converted heat."

There exists a common misapprehension of the heat effect of burning a mixture of gas and air, which produces a non-luminous flame as compared with that from the burning of the stream of gas in the ordinary way of lighting. Either of these ways will clearly evolve equal amount of heat from equal quantities of gas perfectly consumed. But the perfect combustion is ensured by the Bunsen arrangement at times and under conditions when it certainly would fail with the common burner. Where the flame of a simple gas jet is brought in contact with any cold body, or cooled by radiation from any cold body near to it, it is likely to be extinguished and to create not only a smoke of unconsumed particles of carbon, but also produce a large proportion of partly burned carbon, or CO, in the gases of combustion. This last product will follow an inadequate supply of air to the gas. Thus a sheet of gas emerging from a horizontal surface of perforated plate or wire gauze will burn with a nearly non-luminous flame, and will emit a large proportion of carbonic oxide in the products of combustion. The heat expended in the production of light is quite unappreciable, as is established fully by the absorption of light generally with inappreciable evolution of heat, and it is seen that the reasons above stated show the only superiority of the Bunsen flame over the luminous one.

Atmospheric Absorption of Ultra Violet Rays.—Cornu has tested various hypotheses with regard to the atmospheric absorption, which lead him to conclude that the absorption is not due, to any extent, either to the vapor of water or to atmospheric duct, but to the material constitution of the gaseous mass of the atmosphere itself.—*Comptes Rendus.* C.

THE PHOTOPHONE.

By Alexander Graham Bell.

Read before the American Association for the Advancement of Science, August, 1880.

In bringing before you some discoveries made by Mr. Sumner Tainter and myself, which have resulted in the construction of apparatus for the production and reproduction of sound by means of light, it is necessary to explain the state of knowledge which formed the starting point of our experiments. I shall first describe the remarkable substance selenium, and the manipulations devised by various experiments; but the final result of our researches has evidenced the the class of substances sensitive to light vibrations until we can propound the fact of such sensitiveness being a general property of all matter. We have found this property in gold, silver, platinum, iron, steel, brass, copper, zinc, lead, antimony, German silver, Jenkins' metal, Babbitt's metal, ivory, celluloid, gutta percha, hard rubber, soft vulcanized rubber, paper, parchment, wood, mica and silvered glass; and the only substances from which we have not obtained results are carbon and thin microscopic glass. We find that when a vibratory beam of light falls upon these substances they emit sounds—the pitch of which depends upon the frequency of the vibratory change in the light. We find farther that, when we control the form or character of the light-vibration on selenium, and probably on the other substances, we control the quality of the sound and obtain all varieties of articulate speech. We can thus, without a conducting wire as in electric telephony, speak from station to station, wherever we can project a beam of light. We have not had opportunity of testing the limit to which this photophonic influence can be extended, but we have spoken to and from points 213 metres apart; and there seems no reason to doubt that the results will be obtained at whatever distance a beam of light can be flashed from one observatory to another. The necessary privacy of our experiments hitherto has alone prevented any attempts at determing the extreme distance at which this new method of vocal communication will be available. I shall now speak of selenium.

In the year 1817 Berzelius and Gottlieb Gahn made an examination of the method of preparing sulphuric acid in use at Gripsholm. Dur-

ing the course of this examination, they observed in the acid a sediment of a partly reddish, partly clear brown color, which, under the action of the blow-pipe, gave out a peculiar odor, like that attributed by Klaproth to tellurium. As tellurium was a substance of extreme rarity, Berzelius attempted its production from this deposit; but he was unable after many experiments, to obtain further indications of its presence. He found plentiful signs of sulphur mixed with mercury, copper, zinc, iron, arsenic and lead, but no trace of tellurium. It was not in the nature of Berzelius to be disheartened by this result. In science every failure advances the boundary of knowledge as well as every success, and Berzelius felt, that if the characteristic odor that had been observed did not proceed from tellurium, it might possibly indicate the presence of some substance then unknown to the chemist. Urged on by this hope he returned with renewed ardor to his work. He collected a great quantity of the material, and submitted the whole mass to various chemical processes. He succeeded in separating successively the sulphur, the mercury, the copper, the tin and the other known substances whose presence had been indicated by his tests—and, after all these had been eliminated, there still remained a residue which proved upon examination to be what he had been in search of—a new elementary substance. The chemical properties of this new element were found to resemble those of tellurium in so remarkable a degree that Berzelius gave to the substance the name of "selenium," from the Greek wore *selene*, the moon—("tellurium," as is well known, being derived from *tellus*, the earth).

Although tellurium and selenium are alike in many respects, they differ in their electrical properties; tellurium being a good conductor of electricity, and selenium, as Berzelius showed, a non-conductor. Knox discovered in 1837, that selenium became a conductor when fused; and Hittorff, in 1852, showed that it conducted, at ordinary temperatures, when in one of its allotropic forms. When selenium is rapidly cooled from a fused condition it is a non-conductor. In this, its vitreous form, it is of a dark-brown color, almost black by reflected light, having an exceedingly brilliant surface. In thin films it is transparent, and appears of a beautiful ruby red by transmitted light. When selenium is cooled from a fused condition with extreme slowness, it presents an entirely different appearance, being of a dull lead color, and having throughout a granulated or crystalline structure, and looking like a metal. In this form it is perfectly opaque to light,

even in very thin films. This variety of selenium has long been known as "granular" or "crystalline" selenium, or, as Regnault called it, "metallic" selenium. It was selenium of this kind that Hittorff found to be a conductor of electricity at ordinary temperatures. He also found that its resistance to the passage of an electrical current diminished continuously by heating up to the point of fusion, and that the resistance suddenly increased in passing from the solid to the liquid condition. It was early discovered that exposure to sunlight hastens the change of selenium from one allotropic form to another; and this observation is significant in the light of recent discoveries.

Although selenium has been known for the last sixty years, it has not yet been utilized to any extent in the arts, and it is still considered simply as a chemical curiosity. It is usually supplied in the form of cylindrical bars. These bars are sometimes found to be in the metallic condition, but more usually they are in the vitreous or non-conducting form. It occurred to Willoughby Smith that on account of the high resistance of crystalline selenium, it might be usefully employed at the short end of a submarine cable in his system of testing and signaling during the process of submersion. Upon experiment the selenium was found to have all the resistance required—some of the bars employed measuring as much as 1,400 megohms—a resistance equivalent to that which would be offered by a telegraph wire long enough to reach from the earth to the sun! But the resistance was found to be extremely variable. Experiments were made to ascertain the cause of this variability. Mr. May, Mr. Willoughby Smith's assistant, discovered that the resistance was less when the selenium was exposed to light than when it was in the dark.

In order to be certain that temperature had nothing to do with the effect, the selenium was placed in a vessel of water, so that the light had to pass through from one to two inches of water in order to reach the selenium. The approach of a lighted candle was found to be sufficient to cause a marked deflection of the needle of the galvanometer connected with the selenium, and the lighting of a piece of magnesium wire caused the selenium to measure less than half the resistance it did the moment before.

These results were naturally at first received by scientific men with some incredulity, but they were verified by Sale, Draper, Moss and others. When selenium is exposed to the action of the solar spectrum the maximum effect is produced, according to Sale, just outside the red

end of the spectrum, in a point nearly coincident with the maximum of the heat rays; but, according to Adams, the maximum effect is produced in the greenish-yellow or most luminous part of the spectrum. Lord Rosse exposed selenium to the action of non-luminous radiations from hot bodies, but could produce no effect; whereas a thermopile under similar circumstances gave abundant indications of a current. He also cut off the heat rays from luminous bodies by the interposition of liquid solutions, such as alum, between the selenium and the source of light, without affecting the power of the light to reduce the resistance of the selenium; whereas the interposition of these same substances almost completely neutralized the effect upon the thermopile. Adams found that selenium was sensitive to the cold light of the moon, and Werner Siemens discovered that, in certain extremely sensitive varieties of selenium, heat and light produced opposite effects. In Siemens' experiments special arrangements were made for the purpose of reducing the resistance of the selenium employed. Two fine platinum wires were coiled together in the shape of a double flat spiral in the zigzag shape, and were laid upon a plate of mica so that the disks did not touch one another. A drop of melted selenium was then placed upon the platinum wire arrangement, and a second sheet of mica was pressed upon the selenium, so as to cause it to spread out and fill the spaces between the wires. Each cell was about the size of a silver dime. The selenium cells were then placed in a paraffine bath and exposed for some hours to a temperature of 210°C., after which they were allowed to cool with extreme slowness. The results obtained with these cells were very extraordinary; in some cases the resistance of the cells, when exposed to light, was only one-fifteenth of their resistance in the dark.

Without dwelling further upon the researches of others, I may say that the chief information concerning the effect of light upon the conductivity of selenium will be found under the names of Willoughby Smith, Lieutenant Sale, Draper and Moss, Professor W. G. Adams, Lord Rosse, Day, Sabini, Dr. Werner Siemens and Dr. C. W. Siemens. All observations by these various authors had been made by means of galvanometers; but it occurred to me that the telephone, from its extreme sensitiveness to electrical influences, might be substituted with advantage. Upon consideration of the subject, however, I saw that the experiments could not be conducted in the ordinary way, for the following reason: The law of audibility of the telephone is

precisely analogous to the law of electric induction. No effect is produced during the passage of a continuous and steady current. It is only at the moment of change from a stronger to a weaker state, or *vice versa*, that any audible effect is produced, and the amount of effect is exactly proportional to the amount of variation in the current. It was, therefore, evident that the telephone could only respond to the effect produced in selenium at the moment of change from light to darkness, or *vice versa*; and that it would be advisable to intermit the light with great rapidity, so as to produce a succession of changes in the conductivity of the selenium, corresponding in frequency to musical vibrations within the limits of the sense of hearing. For I had often noticed that currents of electricity, so feeble as to produce scarcely any audible effects from a telephone when the circuit was simply opened or closed, caused very perceptible musical sounds when the circuit was rapidly interrupted, and that the higher the pitch of sound the more audible was the effect. I was much struck by the idea of producing sound by the action of light in this way. Upon further consideration it appeared to me that all the audible effects obtained from varieties of electricity could also be produced by variations of light acting upon selenium. I saw that the effect could be produced at the extreme distance at which selenium would respond to the action of a luminous body, but that this distance could be indefinitely increased by the use of a parallel beam of light, so that we could telephone from one place to another without the necessity of a conducting wire between the transmitter and receiver. It was evidently necessary, in order to reduce this idea to practice, to devise an apparatus to be operated by the voice of a speaker, by which variations could be produced in a parallel beam of light corresponding to the variations in the air produced by the voice.

I proposed to pass light through a large number of small orifices, which might be of any convenient shape, but were preferably in the form of slits. Two similarly perforated plates were to be employed. One was to be fixed and the other attached to the centre of a diaphragm actuated by the voice, so that the vibration of the diaphragm would cause the movable plate to slide to and fro over the surface of the fixed plate, thus alternately enlarging and contracting the free orifices for the passage of light. In this way the voice of a speaker could control the amount of light passed through the perforated plates without completely obstructing its passage. This apparatus

was to be placed in the path of a parallel beam of light, and the undulatory beam emerging from the apparatus could be received at some distant place upon a lens, or other apparatus, by means of which it could be condensed upon a sensitive piece of selenium placed in a local circuit with a telephone and galvanic battery. The variations in the light produced by the voice of the speaker should cause corresponding variations in the electrical resistance of the selenium employed; and the telephone in circuit with it should reproduce audibly the tones and articulations of the speaker's voice. I obtained some selenium for the purpose of producing the apparatus shown; but found that its resistance was almost infinitely greater than that of any telephone that had been constructed, and I was unable to obtain any audible effects by the action of light. I believed, however, that the obstacle could be overcome by devising mechanical arrangements for reducing the resistance of the selenium, and by constructing special telephones for the purpose. I felt so much confidence in this that, in a lecture delivered before the Royal Institute of Great Britain, upon the 17th of May, 1878, I announced the possibility of hearing a shadow by interrupting the action of light upon selenium. A few days afterward my ideas upon this subject received a fresh impetus by the announcement made by Mr. Willoughby Smith before the Society of Telegraph Engineers that he had heard the action of a ray of light falling upon a bar of crystalline selenium, by listening to a telephone in circuit with it.

It is not unlikely that the publicity given to the speaking telephone during the last few years may have suggested to many minds in different parts of the world somewhat similar ideas to my own.

Although the idea of producing and reproducing sound by the action of light, as described above, was an entirely original and independent conception of my own, I recognize the fact that the knowledge necessary for its conception has been disseminated throughout the civilized world, and that the idea may, therefore, have occurred to many other minds. *The fundamental idea, on which rests the possibility of producing speech by the action of light, is the conception of what may be termed an undulatory beam of light in contradistinction to a merely intermittent one.* By an undulatory beam of light I mean a beam that shines continuously upon the selenium receiver but the intensity of which upon that receiver is subject to rapid changes, corresponding to the changes in the vibratory movement of a particle of air during the transmission of a sound of definite quality through the atmosphere.

The curve that would graphically represent the changes of light would be similar in shape to that representing the movement of the air. I do not know whether this conception had been clearly realized by "J. F. W.," of Kew, or by Mr. Sargent, of Philadelphia, but to Mr. David Brown, of London, is undoubtedly due the honor of having distinctly and independently formulated the conception, and of having devised apparatus—though of a crude nature—for carrying it into execution. It is greatly due to the genius and perseverance of my friend, Mr. Sumner Tainter, of Watertown, Mass., that the problem of producing and reproducing sound by the agency of light has at last been successfully solved.

The first point to which we devoted our attention was the reduction of the resistance of crystalline selenium within manageable limits. The resistance of selenium cells employed by former experimenters was measured in millions of ohms, and we do not know of any record of a selenium cell measuring less than 250,000 ohms in the dark. *We have succeeded in producing sensitive selenium cells measuring only 300 ohms in the dark, and 155 ohms in the light.* All former experimenters seemed to have used platinum for the conducting part of their selenium cells, excepting Werner Siemens, who found that iron and copper might be employed. We have also discovered that brass, although chemically acted upon by selenium, forms an excellent and convenient material; indeed, we are inclined to believe that the chemical action between the brass and selenium has contributed to the low resistance of our cells by forming an intimate bond of union between the selenium and brass. We have observed that melted selenium behaves to the other substances as water to a greasy substance, and we are inclined to think that when selenium is used in connection with metals not chemically acted upon by it, the points of contact between selenium and the metal offer a considerable amount of resistance to the passage of a galvanic current. By using brass we have been enabled to construct a large number of selenium cells of different forms. The mode of applying the selenium is as follows: The cell is heated, and when hot enough a stick of selenium is rubbed over the surface. In order to acquire conductivity and sensitiveness, the selenium must next undergo a process of annealing.

We simply heat the selenium over a gas stove and observe its appearance. When the selenium attains a certain temperature, the beautifully reflecting surface becomes dimmed. A cloudiness gradually

extends over it, somewhat like the film of moisture produced by breathing upon a mirror. This appearance gradually increases, and the whole surface is soon seen to be in the metallic granular or crystalline condition. The cell may then be taken off the stove, and cooled in any suitable way. When the heating process is carried too far, the crystalline selenium is seen to melt. Our best results have been obtained by heating the selenium until it crystallizes, and continuing the heating until signs of melting appear, when the gas is immediately put out. The portions that had melted instantly recrystallize, and the selenium is found upon cooling to be a conductor, and to be sensitive to light. The whole operation occupies only a few minutes. This method has not only the advantage of being expeditious, but it proves that many of the accepted theories on this subject are fallacious. Our new method shows that fusion is unnecessary; that conductivity and sensitiveness can be produced without long heating and slow cooling: and that crystallization takes place during the heating process. We have found that on removing the source of heat immediately on the appearance of the cloudiness, distinct and separate crystals can be observed under the microscope, which appear like leaden snow-flakes on a ground of ruby-red. Upon removing the heat, when crystallization is further advanced, we perceive under the microscope masses of these crystals arranged like basaltic columns standing detached from one another; and at a still higher point of heating, the distinct columns are no longer traceable, but the whole mass resembles metallic pudding stone, with here and there a separate snow-flake, like a fossil, on the surface. Selenium crystals formed during slow cooling after fusion present an entirely different appearance, showing distinct facets.

We have devised about fifty forms of apparatus for varying a beam of light in the manner required, but only a few typical varieties need be shown. The source of light may be controlled or a steady beam may be modified at any point in its path. The beam may be controlled in many ways. For instance, it may be polarized and then affected by electrical or magnetic influences in the manner discovered by Faraday and Dr. Ker. The beam of polarized light, instead of being passed through a liquid, may be reflected from the polished pole of an electro-magnet. Another method of affecting a beam of light is to pass it through a lens of variable focus. I observe that a lens of this kind has been invented in France by Dr. Cusco, and is fully described in a recent paper in *La Nature*, but Mr. Tainter and I have used such

a lens in our experiments for months past. The best and simplest form of apparatus for producing the effect remains to be described. This consists of a plane mirror of flexible material—such as silvered mica or microscope glass. Against the back of this mirror the speaker's voice is directed. The light reflected from this mirror is thus thrown into vibrations corresponding to those of the diaphragm itself.

In arranging the apparatus for the purpose of reproducing sound at a distance, any powerful source of light may be used, but we have experimented chiefly with sunlight. For this purpose a large beam is concentrated by means of a lens upon the diaphragm mirror and after reflection is again rendered parallel by means of another lens. The beam is received at a distant station upon a parabolic reflector, in the focus of which is placed a sensitive selenium cell, connected in a local circuit with a battery and telephone. A large number of trials of this apparatus have been made with the transmitting and receiving instruments so far apart that sounds could not be heard directly through the air. In illustration I shall describe one of the most recent of these experiments. Mr. Tainter operated the transmitting instrument, which was placed on the top of the Franklin school-house in Washington, and the sensitive receiver was arranged in one of the windows of my laboratory, 1325 L street, at a distance of 213 metres. Upon placing the telephone to my ear I heard distinctly from the illuminated receiver the words "Mr. Bell, if you hear what I say, come to the window and wave your hat." In laboratory experiments the transmitting and receiving instruments are necessarily within earshot of one another, and we have, therefore, been accustomed to pooling the electric circuit connected with the selenium receiver, so as to place the telephones in another room. By such experiments we have found that articulate speech can be reproduced by the oxyhydrogen light, and even by the light of a kerosene lamp. The loudest effects obtained from light are produced by rapidly interrupting the beam by the perforated disk. The great advantage of this form of apparatus for experimental work is the noiselessness of its rotation, admitting the close approach of the receiver without interfering with the audibility of the effect heard from the latter; for it will be understood that musical tones are emitted from the receiver when no sound is made at the transmitter. A silent motion thus produces a sound. In this way musical tones have been heard even from the light of a candle. When distant effects are sought, another apparatus is used. By placing an opaque screen near

the rotating disk, the beam can be entirely cut off by a slight motion of the hand, and musical signals like the dots and dashes of the Morse telegraph code can thus be produced at the distant receiving station.

We have made experiments with the object of ascertaining the nature of the rays that affect selenium. For this purpose we have placed in the path of an intermittent beam various absorbing substances. Professor Cross has been kind enough to give me his assistance in conducting these experiments. When a solution of alum or bisulphide of carbon is employed, the loudness of the sound produced by the intermittent beam is very slightly diminished; but a solution of iodine in bisulphide of carbon cuts off most, but not all, of the audible effect. Even an apparently opaque sheet of hard rubber does not entirely do this. When the sheet of hard rubber was held near the disk interrupter, the rotation of the disk interrupted what was then an invisible beam, which passed over a space of about twelve feet before it reached the lens, which finally concentrated it upon the selenium cell. A faint but perfectly perceptible musical tone was heard from the telephone connected with the selenium. This could be interrupted at will by placing the hand in the path of the invisible beam. It would be premature, without further experiments, to speculate too much concerning the nature of these invisible rays, but it is difficult to believe that they can be bent rays, as the effect is produced through two sheets of hard rubber containing between them a saturated solution of alum. Although effects are produced as above shown by forms of radiant energy which are invisible, we have named the apparatus for the production and reproduction of sound in this way "The Photophone," because an ordinary beam of light contains the rays which are operative.

It is a well known fact that the molecular disturbance produced in a mass of iron by the magnetizing influence of an intermittent electrical current can be observed as sound by placing the ear in close contact with the iron. It occurred to us that the molecular disturbance produced in crystalline selenium by the action of an intermittent beam of light should be audible in a similar manner without the aid of a telephone or battery. Many experiments were made to verify this theory without definite results. The anomalous behavior of the hard rubber screen suggested the thought of listening to it also. This experiment was tried with extraordinary success. I held the sheet in close contact with my ear, while a beam of intermittent light was

focused upon it by a lens. A distinct musical note was immediately heard. We found the effect intensified by arranging the sheet of hard rubber as a diaphragm, and listening through a hearing tube. We then tried crystalline selenium in the form of a thin disk, and obtained a similar but less intense effect. The other substances which I enumerated at the beginning of my address were now successively tried in the form of thin disks, and sounds were obtained from all but carbon and thin glass. We found hard rubber to produce a louder sound than any other substance we tried, excepting antimony, and paper and mica to produce the weakest sounds. *On the whole, we feel warranted in announcing as our conclusion that sounds can be produced by the action of a variable light from substances of all kinds, when in the form of thin diaphragms.* We have heard from interrupted sunlight very perceptible musical tones through tubes of ordinary vulcanized rubber, of brass, and of wood. These were all the materials at hand in tubular form, and we have had no opportunity since of extending the observations to other substances.

I am extremely glad that I have the opportunity of making the first publication of these researches before a scientific society, for it is from scientific men that my work of the last six years has received its earliest and kindest recognition. I gratefully remember the encouragement which I received from the late Professor Henry at a time when the speaking telephone existed only in theory. Indeed, it is greatly due to the stimulus of his appreciation that the telephone became an accomplished fact. I cannot state too highly also the advantage I received in preliminary experiments on sound vibrations in this building from Professor Cross, and near here from my valued friend Dr. Clarence J. Blake. When the public were incredulous of the possibility of electrical speech, the American Academy of Arts and Sciences, the Philosophical Society of Washington, and the Essex Institute of Salem recognized the reality of the results and honored me by their congratulations. The public interest, I think, was first awakened by the judgment of the very eminent scientific men before whom the telephone was exhibited in Philadelphia, and by the address of Sir William Thomson before the British Association for the Advancement of Science.

At a later period, when even practical telegraphers considered the telephone as a mere scientific toy, Professor John Pierce, Professor Eli W. Blake, Dr. Channing, Mr. Clark and Mr. Jones, of Provi-

dence, R. I., devoted themselves to a series of experiments for the purpose of assisting me in making the telephone of practical utility; and they communicated to me, from time to time, the result of their experiments with a kindness and generosity I can never forget. It is not only pleasant to remember these things and to speak of them, but it is a duty to repeat them, as they give a practical reputation to the often repeated stories of the blindness of scientific men to unaccredited novelties, and of their jealousy of unknown inventors who dare to enter the charmed circle of science. I trust that the scientific favor which was so readily accorded to the telephone may be extended by you to this new claimant, the photophone.

Solidification under Pressure.—Walther Spring has investigated the phenomena of universal regelation, or, in other words, the property which the particles of solid bodies possess of uniting by cohesive action under pressure. The pressure in some of his experiments exceeded 20,000 atmospheres, but in the majority of cases from 2,000 to 3,000 atmospheres were sufficient to secure his results. He concludes that all solid bodies possess the property of uniting when they are in close contact. This property is more or less pronounced in different bodies, and it appears to be a function of the hardness. Soft bodies are easily soldered; hard bodies, with difficulty. There is, however, another element which influences the union, to which he gives the name of waxiness, and which is illustrated by Tresca's experiments upon the flow of solids. In every case the bodies which were submitted to pressure were changed into a denser variety; prismatic sulphur, for example, which has a specific weight of 1·96, was changed into octahedric sulphur, with a specific weight of 2·05. We may infer from this fact that the state which matter assumes depends somewhat upon the volume which it is obliged to occupy, through the action of external forces. These experiments seem calculated to throw new light upon some important geological questions; the layers of primary rocks, for example, may have resulted from the union of the grains of sand or mud which were borne along by the waters; the great pressure would have ground and thrust and broken and soldered them anew so as to give them the form which they now possess; faults and cleavages of every description would be comparable to the crevices of glaciers.—*Bull de l'Acad. Roy. de Belg.* C.

PARAFFINE AS A PROTECTION TO WOOD AND IRON.

By Dr. Eugen Schal.

In chemical technology great difficulties sometimes arise when it is desired to manufacture on a large scale preparations which may be obtained with ease in the laboratory. In most cases the reason of this failure is the fact that in the manufacture the use of glass, porcelain, platinum, etc., which successfully resist the effects of the various chemical agents must be dispensed with, and cheaper and less easily breakable materials, such as iron, copper, lead and wood, substituted. Wood especially cannot be replaced by any other material in the wholesale preparation of muriatic lyes, although the same, according to the strength and temperature of the liquid, undergoes sometimes very rapid destruction.

Dr. Schal says he acquired this experience more particularly in 1874–77, in alizarine manufactories, and that he found in paraffine a means which efficiently protects the wood against damp, acids and alkalis, and by which a great saving is effected. The wooden vessels used, especially tanks of pine wood, for boiling acid and alkaline lyes, as well as casks of oak of the heaviest weights, for separating acid alizarine lyes at a pressure of a half to two atmospheres, were generally totally rotten after a few months, but they lasted for two years when impregnated with paraffine.

Before treating with paraffine, however, the vessels must be thoroughly dried for about three weeks by leaving them in warm and dry air, in order to prepare the wood for the absorption of the paraffine solution in its pores. The latter solution is prepared in the following manner. A part of the paraffine is melted in a spacious metal vessel over a moderate fire, the mass being stirred, the boiler taken from the fire, best moved into the open air, stirred until the mass begins to congeal at the edge, and then about six parts of petroleum, ether, or sulphuret of carbon are poured in, and stirred until solution. The preparation is then put into vessels that may be hermetically closed, or it may be used at once. In preparing the paraffine solution great care must be exercised, as paraffine as well as petroleum ether or sulphuret

of carbon especially are very inflammable, and as even the vapor of the two last mentioned substances, if mixed with air, may give rise to dangerous explosions. Those substances must, therefore, be kept in a cool space, far from light or fire, and well stoppered.

The wood is best saturated in dry and warm weather, as then it dries more quickly, and a smaller quantity of the solving agent is necessary. In winter six parts of the solvent generally do not suffice. This proportion changes with the quality of the paraffine and the temperature; paraffine solving with difficulty is better than the more readily soluble article. Vessels easy of access, such as tanks, tubs, etc., are coated in the open air with the solution as long as the wood will absorb it. The solvents evaporate very quickly, leaving the paraffine behind, so that two or three coatings may be laid on in succession. If the vessel is to be exceptionally well prepared, it is left for a day to dry, and then another layer of the paraffine given.

For vessels in which steam is used for boiling the liquids they contain, he applies after a few days a coating of oil varnish, because the melting point of paraffine is below the boiling point of water, and it is thus in time driven out of the pores by the water.

Instead of oil varnish, the vessels, after being well rubbed down, may also be coated with a thin solution of soluble glass, then dried, and washed with diluted hydrochloric acid. The silicic acid thus formed clogs up the pores from the outside, and provides a protection to the paraffine against the hot water. For vessels which are used only with a moderate heat or cold, the coating of paraffine suffices perfectly. The paraffine is hardly dissolved by diluted cold alcohol, is not poisonous, and may also probably be used with advantage for vessels for keeping liquid. In the case of barrels, the solution was poured in simply after drying them; for an oak barrel holding 9 to 10 hectolitres, one kilo of paraffine dissolved in petroleum ether was required. All openings were then well closed and the barrel rolled about and over for about an hour, so as to bring all parts in contact with the solution. The barrels were finally left standing on their ends for half a day, after which time the remainder not absorbed was emptied, and used for the outside coating. Before applying the solution outside, however, the barrels must be well cleaned, for dirt naturally closes the pores of the wood. As these barrels were very expensive, and had to sustain a pressure of two atmospheres, besides being exposed to a high

temperature, they received on both sides an additional coating of oil varnish. It is, however, necessary to let such a barrel stand in the open air at least a fortnight for drying, and as a precaution fire must be kept away from the barrel while being prepared. As a further precaution, in applying the solution inside, the workman must not be left alone, as it frequently happens that stupefying vapors from the solvent of the paraffine arise, which stupefaction, however, soon disappears in the open air. The oil varnish may also be diluted with petroleum ether, poured into the barrel, and then the latter rolled about, as above described; but many places escape saturation in this operation. After coating with varnish, the barrel is once more dried, and then filled with water, in order to force out the combustible gases.

This is much to be advised, as an explosion once took place in consequence of a workmen trying to enlarge a hole with a red-hot iron, contrary to orders. After the last operation, the inner sides of the various vessels were rubbed down with a dry duster, so as to take off all loose particles.

If impregnation of wood is intended on a large scale, the wood is best stacked in iron boxes, the paraffine solution poured over it, the solution not absorbed drawn off after some time, the solvent forced out of the wood by means of warm air, and recovered by condensation in a cooling apparatus.

If the various manipulations are carefully carried out, the duration of vessels thus prepared is increased from four to six fold, while the outlay is comparatively small leaving out of consideration that the contents of such vessels are frequently lost by the bottom being forced out.

Paraffine, melted with equal parts of linseed oil or rapeseed oil, is also useful for coating iron vessels, which without a substantial preservative are very liable to rust in manufactories of chemicals.

Paraffine likewise protects skin efficiently against wet, alkalis (especially lime), acids, etc.

I have often noticed that workmen in alizarine factories suffered much from sore, ulcerating and swollen hands, especially during winter. After the workmen began to use (twice daily) a solution of paraffine with rapeseed oil and petroleum, chapped hands (not to mention swollen or ulcerated hands) became a scarcity.

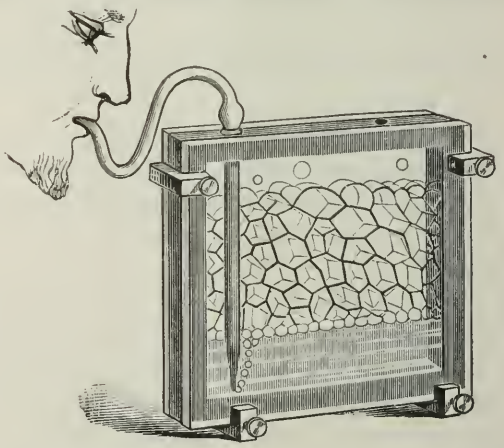
The solution is produced by melting three parts each of paraffine and

rapeseed oil, removing it from the fire, and adding eight parts of petroleum while stirring the mixture. Before using, the solution is stirred a little, and the hands rubbed with it while they are clean and dry. In larger factories, earthenware and tin vessels, filled with this ointment, are placed at convenient spots, and it is believed that the manufacturer as well as the workmen will find this pay.—*Würtembergische Gewerbeblatt.*

HOLMAN'S NEW ILLUSTRATION OF CELL-FORMATION.

By JOHN M. CHILD, A.M.

Mr. D. S. Holman has devised a new illustration of great simplicity and beauty, whereby the method of the formation of cells in vegetable structure may be conveniently shown to an audience. The apparatus consists merely of a tank, which is formed by two pieces of plate-glass, held apart at the bottom and sides by a rubber strip and kept in place by four clamps. In this tank is placed a portion of a soap solution, which is raised in bubbles by a current of air blown into it through a fine glass tube. As the bubbles are formed their tendency to become spheres in virtue of the force of cohesion in their liquid walls is overcome by the capillary attraction of the sides of the tank.



By consequence the films extend across the tank perpendicular to the walls, and the pressure of one bubble upon another causes the forma-

tion of polygonal forms, analogous to those that we see in cross sections of wood fibre. The accompanying figure gives an idea of the appearance that the tank presents when thus filled with bubbles, but does not and cannot portray the beauty of the projection of it which may be made upon a screen. The pencil of rays passing from the condensing lens of a stereopticon is convergent; and as a consequence many rays fall upon the soap films at such a large incident angle that they are almost entirely reflected, and so are tinged with the rich colors resulting from the interference of rays that fall on thin films.

We thus have before us a proof of the tenuity of a layer which is between the limits of $\frac{1}{17000}$ and $\frac{1}{15000}$ of an inch, the latter limit being reached when the color of the film disappears.

The same illustration also affords us an exemplification of the principle, shown in nature in the structure of the honeycomb, that the pressure on each other of equal circles produces a hexagonal structure. Where, in consequence of the regularity of the current of air, we have produced bubbles nearly uniform in size we notice that the polygons formed are six-sided, and that those of a different number of sides exist where there is a diversity in the size of the air-masses.

Friends' Central School, Philadelphia.

Successive Transformations of Photographic Images.—Janssen has reported some additional results of his investigations into the reversals of images by the prolongation or augmentation of luminous energy. He has succeeded in obtaining the following successive transformations: 1. the ordinary negative image; 2. a first neutral state, the plate becoming uniformly obscure under the action of the developer; 3. a positive image which succeeds the first neutral state; 4. a second neutral state, opposed to the first, the plate becoming uniformly clear by the action of the developer; 5. a second negative image, similar to the ordinary negative image, but differing from it by the intermediate states which separate them and by the enormous difference of luminous intensity which is required to obtain it; 6. a third neutral state, in which the second negative image has disappeared and been replaced by a uniform sombre tint. To obtain the second negative image a luminous intensity is required more than a million times as great as that which gives the ordinary negative image.—*Comptes Rendus.* C.

ON THE PROPER FORM OF LIGHTNING CONDUCTORS.

By William Henry Preece.

Read before the British Association, Aug. 27, 1880.

A lightning conductor erected for the protection of a building consists of a ribbon, rod, chain, rope, or other mass of metal attached to the highest point of the structure, and descending to the earth. What shall be the form of this conductor, has been a vexed question from the days of Franklin to the present. Shall it be dependent on extent of surface or on sectional area? In other words, does the transference of electricity when the potentials are so high as to cause lightning discharges, obey the law of Ohm, or is this law modified by the presence of some fresh condition? Snow Harris was a very warm advocate of the surface form. He used flat ribbons for his ships, and tubes for his buildings. Henry, of Washington, believed in the efficacy of surface. According to him, frictional electricity passes at the surface, galvanic electricity through the mass. M. Melsens is found on the same side, and Guillemin, of Paris, led many French electricians to favor the same view.

On the other hand, Faraday almost angrily espoused the opposite side. "As respects electrical conduction," said he, "no advantage is gained by expanding the rod horizontally into a strap or tube. Surface does nothing; the solid section is the essential element."

The advocates of the solid and cylindrical form argue that the lightning conductor is simply a path by which electricity is transferred from a point of high potential (an electrified cloud) to a point of lower potential (the earth), and that its efficacy depends solely upon its resistance. It obeys the law of Ohm, and its efficacy is therefore for the same material dependent on its mass and sectional area.

The advocates of surface argue, that as in all cases of static charge electricity exists only on the surface, so when electricity of "high tension" is conducted away it is the surface that plays the prime part, and, therefore, the greater the surface the easier the path to the discharge. Again, they say when a cylindrical conductor conveys a charge of electricity it is raised to a "high tension," and is rendered capable of doing mischief; but with the same charge, the greater the surface the

less the density on the surface, and, therefore, the greater the safety. In other words, with a given quantity of electricity, the greater the surface the less the potential. Moreover, they urge, since according to Guillemin currents of electricity flowing in the same direction retard each other with a power varying with the distance separating them, and since a rod may be considered as a bundle of smaller but parallel rods, so a current of electricity may be considered as being made up of many parallel currents, each retarding the other. Hence a ribbon will conduct better than a rod, because the currents are spread further apart, and retard each other less. These arguments have led to the employment of unsightly ribbons and expensive tubes, which have considerably interfered with the establishment of this very necessary element of safety to buildings.

The arguments in favor of the surface form are, in the opinion of the author, deductions from exploded theories, from imperfect experiments, or from erroneous interpretations of well-ascertained facts. No direct experiments have ever been made to solve the question, as far as the author knows. Quantities of electricity, that is, static discharges from condensers, are in incessant use for telegraphic purposes, and are found to follow exactly Ohm's law, even with the most delicate apparatus. The knowledge of the flow of electricity through conductors, of the retarding influence of electro-static capacity upon this flow, and of the distribution of charge, has become so much greater of late years through the great extension of submarine telegraphy and the labors of Sir William Thompson, Clerk-Maxwell and others, that I question if any English electrician would now be found to argue in favor of the surface form. Nevertheless, ribbons and tubes still continue to be used, and it appeared very desirable to settle the question experimentally. I determined to try and do so.

First Experiments, June 28, 1880.—Dr. Warren de la Rue, who is always ready to place his splendidly equipped laboratory at the service of science, not only allowed me to use his enormous battery and his various appliances, but aided me by his advice, and assisted me in conducting the experiments.

Copper conductors, 30 feet long, of precisely the same mass (*a*), drawn into a solid cylinder (*b*) made into a thin tube, and (*c*) rolled into a thin ribbon were first of all obtained. The source of electricity was 3240 chloride of silver cells. The charge was accumulated in a condenser of a capacity of 42·8 microfarads. It was discharged through

platinum wire of ·0125 diameter, of different lengths. The sudden discharge of such a large quantity of electricity as that contained by 42·8 mf. raised to a potential of 3317 (the electro-motive force of the chloride of the silver cell being 1·03 volt) volts is very difficult to measure, it partakes very much of the character of lightning. In fact the difference of potential per unit length of air is probably greater than that of ordinary lightning itself. It completely deflagrates 2½ inches of the platinum wire, but by increasing the length of the wire it could be made to reproduce all the different phases of heat which are indicated by the various shades of red until we reach white heat, fusion, and deflagration. Hence the character of the deflagration, which is faithfully recorded on a white card, to which the wire is attached, by its scattered particles, is a fairly approximate measure of the charge that has passed, while the length of wire, raised to a dull red heat, is a better one, for any variation in the strength of the current within moderate limits is faithfully recorded by the change of color.

Experiment 1.—Similar charges were passed through the ribbon, tube and wire, and in each case 2½ inches of wire were deflagrated. No difference whatever could be detected in the character of the deflagration.

Experiment 2.—Ten inches of wire were taken and similar charges passed through. In each case the wire was raised to very bright redness, bordering on the fusion point, and in two cases the wire broke. In each case the wire knuckled up into wrinkles, and gave evidence of powerful mechanical disturbance. The same wire was not used a second time. No difference could be detected in the effect through the different conductors.

Experiment 3.—Silver wire of the same diameter and length was used, and similar charges transmitted through it. Redness was barely visible, but the behavior of the wire was similar in each case.

The conclusion arrived at unhesitatingly was that change of form produced no difference whatever in the character of the discharge, and that it depended simply on mass.

Second Experiments, July 19, 1880.—As it might be urged that the length of conductor tested was so short, and its resistance so small, that considerable variations might occur and yet be invisible; similar lengths (30 feet) of lead—a very bad conductor, its resistance being twelve times that of copper—were obtained, drawn as a wire, made as a tube, and rolled as a ribbon, each being of similar weight.

Experiment 4.—Charges from the same condenser, 42·8 mf., but with 3280 cells, were passed through, and the discharges observed on 6 inches of platinum wire 0·0125 inches diameter, which in each case was heated to bright redness. No variation whatever could be detected, whether the wire, the tube or the ribbon were used.

Experiment 5.—In order to form some idea as to how closely we could estimate any variation in the character of the discharge, we used a long piece of platinum wire and adjusted the lengths until we obtained just visible redness; then a diminution of 10 per cent. (3 feet) produced a marked change to dull redness, and further excisions raised the temperature to brighter and still brighter red.

The conclusion arrived at was that any change in resistance of 5 per cent. would have been clearly and easily discernible.

It therefore appears proved that the discharges of electricity of high potentials obey the law of Ohm, and are not affected by change of form. Hence, extent of surface does not favor lightning discharges. No more efficient lightning conductor than a cylindrical rod or a wire rope can therefore be devised.

JOSEPH HENRY.

By Prof. A. M. Mayer.

Read before the American Association for the Advancement of Science, August, 1880.

At the meeting of the association in 1878, a committee, composed of Professors Baird, Newcomb and myself, was appointed to prepare a eulogy on our revered and lamented colleague and former president, Joseph Henry. This—I will not say labor, but duty of affection—has devolved on me alone. I would that the other members of this committee had laid before you their tributes to his memory, because for years they had been closely associated with him in his social and professional life in Washington. Yet, while Professor Henry had been the friend of their manhood, he was the friend of my boyhood; and during twenty-five years he ever regarded me—as was his wont to say—with a "paternal interest." To his disinterested kindness and wise counsels is due much, very much, of whatever usefulness there is in me. Hence I have said that it is a duty of affection for me to speak to you about one who was my beloved friend. I shall not,

however, attempt a biography of Joseph Henry, nor will I speak of his administrative life as director of the Smithsonian Institution, for this is known and valued by the whole world. His best eulogy is an account of his discoveries; for a man of science, *as such*, lives in what he has *done*, and not in what he has *said;* nor will he be remembered in what he proposed to do. I will, therefore, with your permission, confine myself chiefly to Henry *as the* discoverer; and I do this the more willingly because I am familiar with his researches, and also because Professor Henry, from time to time, took pleasure in giving me accounts of those mental conceptions which preceded his work, led him to it, and guided him in it. Rightly to appreciate a discoverer we should not look at his work from our time, but go back and regard it from his time; we should not judge his work in the fulness of the light of present knowledge, but in the dim twilight which alone illuminated him to then unknown—but now well known—facts and laws. I will, therefore, endeavor first to present you with a clear, but necessarily very concise, view of the state of our knowledge of electricity when Henry began his original researches in that branch of science, and then point out the value of his discoveries by showing what they added to knowledge, and how they instigated and influenced the discoveries and inventions of other men. Henry began his electrical researches at the age of twenty-eight, in the year 1827, while he was professor of mathematics and natural philosophy in the Albany Academy. At these he continuously worked till 1832, when, at the age of thirty-three, he moved to Princeton College. After a year's break in his work, caused by the preparation of his course of lectures for the college, he is again at original research, and continues his contributions to electrical discoveries till 1842. Thus, during fourteen years, between the ages of twenty-eight and forty-three, he was a constant and fertile worker.

As with many other men of originality, Henry's first essays were in the direction of improving the means of illustrating well-established scientific facts and principles. His first paper, of October, 1827, is interesting because it was his first. In it he improves on the usual apparatus which had been used by Ampère and others to show electrodynamic actions, by employing several turns of insulated wire instead of one, as had previously been the practice. Thus, for example, to show the directive action of the earth's magnetism on a freely moving closed circuit, Henry covered copper wire with silk, and then made

out of it a ring about twenty inches in diameter, formed of several turns of the wire. The extremities of this wire were soldered to zinc and copper plates. The coil was then suspended by silk filaments. On plunging the metal plates into a glass of dilute acid the ring rotated around its point of suspension till its plane took a permanent position at right angles to the magnetic meridian. By a similar arrangement of two concentric coils, one suspended within the other, he neatly showed the mutual actions of voltaic currents flowing in the same or opposite directions, which facts are the foundations of Ampère's celebrated law. We now reach a period when Henry appears as a discoverer, and truly one of no mean order. As I remember his narration to me in the year 1859, it was as follows: He said that one evening he was sitting in his study in Albany with a friend, when, after a few moments of reverie, he arose and exclaimed, "To-morrow I shall make a capital experiment!" For several months he had been brooding over Ampère's electro-dynamic theory of magnetism, and he was then deeply interested in the phenomena of the development of magnetism in soft iron, as shown in the experiments of Arago and Sturgeon. At the moment he had arisen from his chair it had occurred to him that the requirements of the theory of Ampere were not fulfilled in the electro-magnets of Arago and Sturgeon, but that he could get those conditions which the theory required by covering the enveloping wire with a non-conductor like silk, and then wrapping it closely around the soft iron bar in several layers; for the successive layers of wire, coiling first in one direction and then in the other, would tend to produce a resultant action of the current at right angles to the axis of the bar; and furthermore, the great number of convolutions thus obtained would act on a greater number of molecules of the bar, and therefore exalt its magnetism. "When this conception," said Henry, "came into my brain, I was so pleased with it that I could not help rising to my feet and giving it my hearty approbation." Henry did go to work the next day, and, to his great delight and encouragement, discoveries of the highest interest and importance revealed themselves to him week after week. When he had finished his newly conceived magnet he found that it supported several times more weight than did Sturgeon's magnet of equal size and weight. This was his first original discovery.

I will now give, as far as possible, Henry's own words in narrating his subsequent investigations of these very interesting phenomena:

"The maximum effect, however, with this arrangement and a single battery was not yet obtained. After a certain length of wire had been coiled upon the iron the power diminished with a further increase of the number of turns. This was due to the increased resistance which the larger wire offered to the conduction of electricity. Two methods of improvement, therefore, suggested themselves. The first consisted, not in increasing the length of coil, but in using a number of separate coils on the same piece of iron. By this arrangement the resistance to the conduction of the electricity was diminished and a greater quantity made to circulate around the iron from the same battery. The second method of producing a similar result consisted in increasing the number of elements of the battery, or, in other words, the projectile force of the electricity, which enabled it to pass through an increased number of turns of wire, and thus, by increasing the length of the wire, to develop the maximum power of the iron. To test these principles on a larger scale an experimental magnet was constructed. In this a number of compound helices were placed on the same bar, their ends left projecting, and so numbered that they could be all united into one long helix, or variously combined in sets of lesser length. From a series of experiments with this and other magnets it was proved that, in order to produce the greatest amount of magnetism from a battery of a single cup, a number of helices is required; but when a compound battery is used, then one long wire must be employed, making many turns around the iron, the length of wire and consequently the number of turns being commensurate with the projectile power of the battery. In describing the results of my experiments the terms *intensity* and *quantity* magnets were introduced to avoid circumlocution, and were intended to be used merely in a technical sense. By the intensity magnet I designated a piece of soft iron so surrounded with wire that its magnetic power could be called into operation by an intensity battery; and by a quantity magnet a piece of iron so surrounded by a number of separate coils that its magnetism could be fully developed by a quantity battery. "I was," said Henry, "the first to point out this connection of the two kinds of the battery with the two forms of the magnet, in my paper in *Silliman's Journal*, January, 1831, and clearly to state that, when magnetism was to be developed by means of a compound battery, one large coil was to be employed, and when the maximum effect was to be produced by a single battery a number of strands were to be used."

We will now return to Henry's study of the properties of his intensity magnet. This magnet was formed of a piece of iron one-fourth of an inch in diameter, bent in the U form and wound with eight feet of insulated wire. His batteries were two—one formed of a single element with a zinc plate four inches by seven, surrounded by copper and immersed in dilute acid; the other a Cruikshank's battery, or trough, with twenty-five double plates. The plates of this battery were joined in series, and altogether had exactly the same surface of zinc as that in the single-cell battery. The magnet was now connected directly to the single cell. The magnet held up seventy-two ounces. Then five hundred and thirty feet of No. 18 copper wire led the current from the cell to the magnet; it now supported only two ounces. Five hundred and thirty feet more of the wire were introduced into the circuit, and then the magnet held but one ounce. In these facts Henry faced the same results as confronted Barlow five years before, and caused Barlow then to say: "In a very early stage of electro-magnetic experiments it had been suggested [by Laplace, Ampère and others] that an instantaneous telegraph might be established by means of conducting wires and compasses, but I found such a sensible diminution with only two hundred feet of wire, as at once to convince me of the impracticability of the scheme"; and such, at that day, seemed to be the common opinion of men of science. But this opinion is presently to be shown by Henry to be ill-founded, by reason of the ignorance of the relations which have of necessity to exist between the kind of battery and the kind of magnet in order to produce electro-magnetic action at a distance—relations which Henry was the first to discover. This accomplishment justly entitles him to be regarded as a man of genius and a discoverer of no mean order. This discovery will always remain the one important fact that was to be known, to be understood and to be applied, before it was possible to have constructed any form of electro-magnetic telegraph. Let us see how Henry made this discovery.

After ending the experiments with the one-cell battery and reaching results which seemed to confirm the opinion of Barlow as to the "impracticability of the scheme" of an electro-magnetic telegraph, Henry attached his magnet to the second battery, formed of twenty-five cells, arranged in series. The current from this battery was sent to the magnet through one thousand and sixty feet of the same wire as had been used in the experiments with the first battery of one cell.

The magnet now lifted eight ounces. It had held up only one ounce, when with the same length of interposed wire the battery of one cell was used. He now attached his electro-magnet directly to the poles of the twenty-five cell battery, when, to his astonishment, it only held seven ounces. The same magnet, it will be remembered, when attached to the one-cell battery, supported seventy-two ounces. Here were facts of the highest significance, and Henry was not slow to seize them in all their bearings. Referring to these experiments, he said, in 1857: "These steps in the advance of electro-magnetism, though small, were such as to interest and astonish the scientific world. These developments were considered at the time of much importance in a scientific point of view, and they subsequently furnished the means by which magneto-electricity, the phenomena of diamagnetism, and the magnetic effects in polarized light were discovered. They gave rise to the various forms of electro-magnetic machines which have exercised the ingenuity of inventors in every part of the world, and were of immediate applicability in the introduction of the magnet to telegraphic purposes. Neither the electro-magnet of Sturgeon nor any electro-magnet ever made previous to my investigations was applicable to transmitting power to a distance."

Not satisfied with the mere statement that his discovery was "directly applicable to Mr. Barlow's project of forming an electro-magnetic telegraph," he actually constructed one, some time during the year 1831, around one of the upper rooms of the Albany Academy. It was more than a mile in length, and made signals by sounding a bell. This was the first electro-magnetic telegraph which had worked through so great a length of wire. It was the first "sounding" electro-magnetic telegraph. The relative parts played by Henry and Morse are described in Henry's "statement" published by the Smithsonian in 1857. "*The principles*," says Henry, "*I had developed were applied by Dr. Gale to render Morse's machine effective at a distance.*" This statement seems to be as direct, as clear, as truthful and as comprehensive as one can desire. I will take the liberty of remarking that had Henry taken out a patent in which he claimed as his invention an electro-magnet formed of two or more layers of insulated wire, Morse's patent would not have been so valuable. Remember, I speak not of the merit of the invention, but of the merit of the patent; for the invention, so far as Morse is concerned, would have

remained the same, because one essential part of a Morse telegraph is Henry's intensity magnet, and certainly Morse never invented that.

If Ohm's law had been known to Henry, with all of its consequences, when applied to his discovery of the exaltation of the electro-magnetism of iron, in connection with his discovery of the proper relations necessary between batteries and magnet to get the greatest electro-magnetic effects, his discoveries would appear dwarfish, though yet of excellent workmanship. But did he at this time, 1827 to 1832, know of Ohm's law? I infer that Henry arrived at his discoveries independently of such knowledge, and for twofold reasons. First, Ohm's law was published as late as 1827, in Berlin, and was received almost contemptuously. Henry was unable to read German, and Ohm's papers were first published in English in 1841. Secondly, from the manner in which Henry worked at his problems and viewed his results, I conclude that he had no knowledge of Ohm's laws; else why should he have been astonished at the effects when his intensity magnet was connected with his intensity battery? Henry, now in possession of powerful magnets, began to work on another problem. He tried to do the reverse of what he had already done. His magnet was made by the action of the electric current, and he now tried to obtain an electric current from the magnet, and he succeeded. Henry and Faraday independently discovered the means of producing an electric current and spark from a magnet. Tyndall speaks of this experimental result as "the Mont Blanc of Faraday's own achievements." A few words now will place Henry in his proper and just relations to these important discoveries. All the information he had received from Faraday's discovery was the account of Farraday's production of magneto-electricity by the sudden insertion of a magnet into a helix and its sudden withdrawal therefrom. Henry's experiment is entirely different, and certainly was entirely original with him; but it is essentially identical with another of Faraday's of which Henry had no knowledge. Thus it appears that, although Henry cannot be placed on record as the *first* discoverer of the magneto-electric current, he stands alone as its *second* independent discoverer.

Henry's next discovery was that of the induction of a current upon itself, or of the extra current, as it is sometimes called. Here he anticipated Faraday by nearly two years and a half in the observation of the fundamental facts. Notwithstanding an explicit disclaimer of Faraday, the credit of this discovery has been generally given to the

latter. This is accounted for by the fact that, although Henry anticipated others in his observations, he had not leisure to follow them up to their full explanation until after Faraday had completely unraveled their nature. In 1838, after his return from a first visit to Europe, Henry discovered an entirely new class of phenomena in electrical induction. He first showed that an induced current may excite a second induced current in a neighboring closed conductor, that this last may induce a third current, and so on. These currents Henry styled currents of the first, second, third, etc., orders, and he showed that they alternate in their direction successively. He investigates the differences in these currents as they flow through different resistances. The same phenomena he tracks through the inductive sections of the discharge of the Leyden jar and of the frictional electrical machine, and shows how they differ from those produced by the voltaic battery. These researches are the most finished of Henry's investigations, and will ever be regarded as models of careful and thorough scientific work.

Henry had a versatile mind, and did not confine his attention to the study of electricity. His researches in molecular physics, though not extensive, are remarkable. Here his suggestions and methods have stimulated others to follow in the paths which he has pointed out. In 1839 Henry made a curious discovery as to the permeability of lead to mercury. He found mercury would even ascend a lead wire to the height of a yard in a few days. He even made what might be called siphons of lead, which would nearly empty a vessel of mercury by drawing the fluid over its sides. Subsequently, in 1845, with Mr. Cornelius, he proved that copper, when heated to the melting point of silver, would absorb the latter metal. In 1844 Henry was investigating the nature of the forces acting in liquid films. Studying the tenacity of the soap bubble film, although his experiments could only furnish approximate results, they showed that the molecular attraction of water for water is really several hundred pounds to the square inch, and probably equal to the attraction of ice for ice. Another of Henry's investigations, having a practical bearing, should be more widely known than it is. Among his duties as chairman of the United States Lighthouse Board was the testing of the various physical properties of the oils submitted to the government for purchase. Fluidity was one of these properties for which it seemed most difficult to get reliable tests. Here he very ingeniously applied the theorem of Torri-

celli, which shows that equal quantities of all liquids of equal fluidity will flow out of an orifice in equal times. Henry found that with different oils the flow of equal quantities differed, the rapidity of flow of sperm oil exceeding that of lard oil in the ratio of 100 to 167. Alcohol proved to be less fluid than water. Henry took a deep interest in acoustics. His additions to this science were chiefly the results of experiments upon fog signals. He made extensive experiments with various sound producing instruments, and eventually decided in favor of the steam siren fog horn. He determined that these instruments send their sound farthest when tuned very near to the treble C, and he also showed the uselessness of applying reflectors to them. During eleven years Henry sought to advance the efficiency of our fog signals by experiments in all weathers. Many very puzzling facts were collected. Thus it was observed that a sound coming to a mariner against the wind would cease to be audible on the deck of his vessel while it continued to be heard at the masthead. It was also observed that upon approaching a fog horn from a distance the intensity of sound would gradually increase, then die down rapidly, become inaudible through a space of three or four miles, and perhaps not reappear until the vessel was within a mile of the instrument. These facts demanded explanation, and for a long time remained enigmas to Henry; till one day he met with a paper by Professor Stokes, in which the effect of an upper current in deflecting a wave of sound is fully explained. This hypothesis of Stokes Henry was able to apply to the solution of the problems in question.

Henry's services to the Lighthouse Board were of great value to the country. The fact that his investigations showed that lard oil heated to about 250° Fahr. is superior in fluidity and illuminating power to sperm oil caused the substitution of the former for the latter. A dollar a gallon was saved, which amounts to about one hundred thousand dollars a year in favor of the government. In light and heat Henry made several investigations which we must pass over. One, however, is so important that it cannot be omitted. I refer to his application of the thermopile to determining the distribution of heat on the optical images of distant objects. In a bold and wonderful experiment he sought to study the distribution of heat on the surface of the sun. In 1845, with Stephen Alexander, he formed an image of the sun, by means of a telescope, upon a screen. In this screen was cut an aperture, closed by the surface of a thermopile. By

a motion of the telescope any part of the image could be brought upon the pile. A solar spot being present, he clearly proved that it emitted less heat than the surrounding parts of the luminous disk. This method of research was shown to Secchi. On his return to Europe the latter made no small repute by extending these observations, using Henry's methods, but often, I fear, not giving full credit to the originator. But let that pass, for the bread which Henry cast upon the waters has returned to our own shores, thanks to the genius of our colleague Langley.

It is impossible to crowd into one brief hour the thoughts which were his occupation during more than half a century. I have at least endeavored to exhibit the more important of the labors of his life. What shall we think of them? Surely they are on as high a plane as those of any of his contemporaries, and show as much originality as theirs in their conception—as much skill in their execution. Yet it has been said that Henry was not a man of genius. As I have not been able to find that the philosophers, who have the special charge of giving from time to time definitions of genius, have been able to come to any satisfactory conclusion among themselves, I will leave their company, and, with your liberty, take my definition from a book which, if we accredit Thackeray, is one of the very best, if not the best, novel ever writ in English. After listening to this I will allow you to form your own opinion as to whether Henry did or did not possess genius. "By genius I would understand that power, or rather those powers of the mind which are capable of penetrating into all things within our reach and knowledge, and of distinguishing their essential differences. These are no other than invention and judgment, and they are both called by the collective name of genius, as they are of those gifts of nature which we bring with us into the world. Concerning each of which, many seem to have fallen into very great errors; for by invention, I believe, is generally understood a creative faculty, which would indeed prove most romance writers to have the highest pretensions to it; whereas by invention is meant no more, and the word so signifies, than discovery in finding out; or, to explain it at large, a quick and sagacious penetration into the true essence of all the objects of our contemplation. This, I think, can rarely exist without the concomitancy of judgment, for how can we be said to have discovered the true essence of two things, without discovering their difference seems to me hard to conceive. Now this last is the undis-

puted province of judgment; and yet some few men of wit have agreed with all the dull fellows in the world in representing these two to have been seldom or never the property of one and the same person." My own judgment, if of any value, would rank the ability of Henry—I do not say his achievements—a little below that of Faraday. Indeed, their lives and their manners of working were strangely alike. Faraday was the son of a blacksmith. He once wrote: "I love a smith's shop and anything relating to smithery. My father was a smith." Henry's father plied a schooner on the Hudson. Each started in life with moral and benevolent habits, well developed and healthy bodies, quick and accurate perceptions, calm judgment and self-reliance, tempered with morality and good manners—a good ground, surely, in which to plant the germs of the scientific life. Faraday was an apprentice to a bookbinder. Henry served in the same capacity under a silversmith. Each, endowed with a lively imagination, was in his younger days fond of romance and the drama; and, by a singular similarity of accidents, each had his attention turned to science by a book which chance threw in his way. This work in the case of Faraday was *Mrs. Marcet's Conversations on Chemistry*, and the book which influenced Henry's career was *Gregory's Lectures on Experimental Philosophy, Astronomy and Chemistry*. Of Mrs. Marcet's book Faraday thus writes: "My dear Friend—Your subject interested me deeply every way; for Mrs. Marcet was a good friend to me, as she must have been to many of the human race. I entered the shop of a bookseller and bookbinder at the age of thirteen, in the year 1804, remaining there eight years, and during the chief part of the time bound books. Now, it was in those books, in the hours of the week, that I found the beginning of my philosophy. There were two that especially helped me—the *Encyclopædia Britannica*, from which I gained my first notions of electricity, and Mrs. Marcet's *Conversations on Chemistry*, which gave me my foundation in that science. Do not suppose that I was a very deep thinker, or was marked a precocious person. I was a burly, imaginative person, and could believe in the *Arabian Nights* as easily as in the *Encyclopædia*. But facts were important to me and saved me. I could trust a fact, and always cross-examined an assertion. So when I questioned Mrs. Marcet's book by such little experiments as I could find means to perform, and found it true to the facts as I could understand them, I felt that I had got hold of an anchor in chemical knowledge, and clung fast to it.

Thence my deep veneration for Mrs. Marcet—first as one who had conferred great personal good pleasure on me, and then as one able to convey the truth and principle of those boundless fields of knowledge which concern natural things to the young, untaught and inquiring mind. You may imagine my delight when I came to know Mrs. Marcet personally; now often I cast my thoughts backward, delighting to connect the past and the present; how often, when sending a paper to her as a thank offering, I thought of my first instructress, and such thoughts will remain with me."

Henry wrote on the inside of the cover of Gregory's work the following words: "This book, although by no means a profound work, has, under Providence, exerted a remarkable influence on my life. It accidentally fell into my hands when I was about sixteen years old, and was the first book I ever read with attention. It opened to me a new world of thought and enjoyment; invested things before almost unnoticed with the highest interest, fixed my mind on the study of nature, and caused me to resolve at the time of reading it that I would immediately begin to devote my life to the acquisition of knowledge —J. H." Each of these philosophers worked with simple instruments, mostly constructed by his own hands, and by methods so direct that he appeared to have an almost intuitive perception into the workings of nature; and each gave great care to the composition of his writings, sending his discoveries into the world clothed in simple and elegant English. Finally, each loved science more than money, and his Creator more than either. There was sympathy between these men, and Henry loved to dwell on the hours that he and Bache spent in Faraday's society. I shall never forget Henry's account of his visit to King's College, London, where Faraday, Wheatstone, Daniell and he had met to try and evolve the electric spark from the thermopile. Each in turn attempted and failed. Then came Henry's turn. He succeeded, calling in the aid of his discovery of the effect of a long interpolar wire wrapped around a piece of soft iron. Faraday became as wild as a boy, and, jumping up, shouted, "Hurrah for the Yankee experiment." And Faraday and Wheatstone reciprocated the high estimation in which Henry held them. During a visit to England, not long before Wheatstone's death, he told me that Faraday and he had, after Henry's classical investigation of the induced currents of different orders, written a joint letter to the council of the Royal Society, urging that the Copley medal, "that laurel wreath of science,"

should be bestowed on Henry. On further consultation with members of the council it was decided to defer the honor till it would come with greater *éclat*, when Henry had continued farther his researches in electricity. Henry's removal to Washington interrupted these investigations. Wheatstone promised to give me this letter to convey to Henry as an evidence of the high appreciation which Faraday and he had for Henry's genius, but Wheatstone's untimely death prevented this. Both Faraday and he gave much thought to the philosophy of education, and in the main their ideas agreed. I may in this connection be excused from reading abstracts from a letter from Henry soon after he had received the news that I had given my son his name. After a playful discussion of the name Joseph, Jo and Josey, he says—what may be news to most of you: "I did not object to Henry as a first name, although I have been sorry that my grandfather, in coming from Scotland to this country, substituted it for Hendrie, a much less common, and therefore, distinctive name." He then proceeds: "I hope that both his body and mind will be developed by proper training and instruction, that he may become an efficient, wise and good man. I say efficient and wise, because these two characteristics are not always united in the same person. Indeed, most of the inefficiency of the world is due to their separation. Wisdom may know what ought to be done, but it requires the aid of efficiency to accomplish the desired object. I hope that in the education of your son due attention may not only be given to the proper development of both these faculties, but also they will be cultivated in the order of nature; that is, doing before thinking, art before science. By inverting this order much injury is frequently done to a child, especially in the case of the only son of a widowed mother, in which a precocious boy becomes an insignificant man. On examination in such a case it will generally be found that the boy has never been drilled into expertness in the art of language, of arithmetic, or of spelling, of attention, perseverance and order, or, in other words, of the habits of an active and efficient life."

Henry was a man of extensive reading, and often surprised his friends by the extent and accuracy of his information, and by the original manner in which he brought his knowledge before them. Not only was he well versed in those subjects in which one might naturally suppose him proficient, but in departments of knowledge entirely distinct from that in which he gained his reputation as an original

thinker. Although without a musical ear he had a nice feeling for the movement of a poem, and was fond of drawing from his retentive memory poetic quotations apt to the occasion. He was a diligent student of mental philosophy, and also took a lively interest in the progress of biographical science, especially in following the recent generalization of Darwin; while the astonishing development of modern research in tracking the history of prehistoric man had for him a peculiar fascination. Yet with all his learning, reputation and influence, Henry was as modest as he was pure. One day, on opening Henry's copy of *Young's Lectures on Natural Philosophy*, a book which he has studied more than any other work of science, I read on the fly-leaf, written in his own hand, these words:

"In Nature's infinite book of secrecy
A little I can read."—*Shakespeare.*

And did he not read a little "in Nature's infinite book of secrecy"? And did he not read that little well? May we all read our little in that book as modestly and as reverently as did Joseph Henry.

WOODBURY-TYPE PHOTO-PLATES—THE OLD AND NEW PROCESS.

We must congratulate Mr. Woodbury upon the success which has rewarded his efforts to reduce photo-relief printing to a simple form. As the method at present stands, with the last finishing touch that has just been given to it, no process of photo-engraving could be more easy or practical. Within a twelvemonth, Woodbury-type has not only become untrammeled by patent, but robbed of every complication that stood in the way of vulgarizing the process. We shall not be surprised, after this, if, when another year has passed, many photographers—or, at any rate, those in the first rank—take to producing their pictures by mechanical means instead of by sunlight, and exchange the frame for the press in their printing department. Already we hear of several Paris houses that have taken up photo-relief printing, while far-off Madrid, it is said, has sent representatives to the French capital to learn if the good news be true.

The lapse of the Woodbury-type patent in England caused several in this country to take up photo-relief printing. Besides those directly interested in the patent may be mentioned the Autotype Company and

the London Stereoscopic Company as among the first to recognize the the value of the process. We all of us know the orthodox method of proceeding. A gelatine pellicle, slightly tinted, but still transparent, was sensitized in a solution of bichromate, and, after drying, exposed under a negative. The surface thus reprinted having been rendered partially insoluble—where the light had got to it through the negative—was then washed in lukewarm water, the result, of course, being an intaglio, or image represented by hollows, more or less deep. This intaglio or mould, when dried and hardened, was put at the bottom of a shallow steel tray, the walls of which were knife edges; a sheet of lead was placed upon the mould, and the whole put under a hydraulic press. Enormous pressure was necessary. In the case of a carte-de-visite picture a pressure of something like 150 tons was required, while in the case of a picture measuring eight or ten inches, no less than a strain of 500 tons was deemed requisite to force the lead into the cavities of the gelatine image. The knife edges cut through the lead, and thus allowed the latter to fill up the tray precisely, a measure indispensable to prevent injury to the gelatine mould.

In this way, then, the engraving plate that served for the printing off of Woodbury-type impressions was made. Not only are the operations very delicate and nice in their nature, but they involve much time and costly apparatus. The mere fact that a hydraulic press, capable of exerting a pressure of from 150 to 500 tons, is a necessity, was of itself sufficient to prevent Woodbury-type being worked by photographers at large, and it was for this reason why only large firms could afford to practice the process. Now Mr. Woodbury shows us how press, steel tray, lead, and hydraulic machinery may be dispensed with altogether, and any photographer, who possesses a rolling press and a supply of tin foil can prepare a properly engraved plate. The modification is so simple that it seems absurd the plan was not thought of before. Mr. Woodbury takes a positive instead of a negative to begin with, and with this produces his gelatine mould. This mould is hardened as before, attached the while to a surface of patent plate, so that its level character may be depended upon. As soon as dry, a sheet of tin foil is placed upon the gelatine mould, and, to force the tin metal securely into every crevice, mould and tin foil are sent through an ordinary rolling press. This is all. The gelatine mould with its lining of lead—for tin foil, as our readers very well know, is simply sheet lead—serves for printing off the Woodbury pictures, and to

judge from the appearance of the prints with which Mr. Woodbury has favored us, the impressions are equal in every respect to those furnished by moulds in which the lead is solid.

Of course there is the making of the gelatine mould in the first place, and the actual printing off of the impressions in the last, and to do these operations well and successfully, some apparatus and some experience are necessary. The experience can obviously only be acquired by practice, but we have no doubt that Mr. Woodbury will see his way to giving instructions as to apparatus and manipulations to British photographers in the same manner as he affords assistance to those abroad. Mr. Woodbury, we believe, is bound by some engagement or agreement not to do any teaching in the matter of photo-relief printing in this country, and hence it is that the important improvements he has recently made known come to us from abroad. The business arrangements between Mr. Woodbury and his co-operators do not, however, concern us, and our duty here is but to chronicle the simple and easy stage to which the photo-relief printing has now been brought.—*Photographic News.*

A NEW POWERFUL AND CONSTANT BATTERY WITHOUT ACID.

By Emile Reynier.

The problem of the abundant and economical production of electricity in the arts has been solved in a satisfactory manner by magneto-electric machines; but in establishments where motive power cannot be obtained, and which are very numerous, recourse must be had to nitric acid batteries, the inconveniences of which are well known.

Many persons have endeavored to obtain batteries which are both powerful and constant, and which at the same time do not give off disagreeable fumes. Up to the present no batteries have fulfilled all these conditions, and the Grove and Bunsen couples have continued to be employed in spite of the disagreeable and hurtful fumes which they give off, and in spite of their expensive nature and the trouble they give in requiring to have their zincs amalgamated, their contacts cleaned, etc., operations which must be repeated each time the battery is set up.

I have tried, amongst many other things, to get rid of these inconveniences, and to a very great extent have succeeded by means of my new battery, of which the following is an account.

The zinc of this new battery is plunged into a solution of caustic soda, the negative electrode, which is of copper, is depolarized by a solution of sulphate of copper, separated from the alkaline solution by a porous cell. The couple thus arranged is constant. Its electro-motive force is considerable, being from 1·3 to 1·5 volts, according to the degree of concentration of the solutions.

The solutions of soda and sulphate of copper have a medium conductivity; I have diminished their resistance by the addition of certain selected salts. On the other hand, I have notably reduced the resistance of the porous chamber by employing for that purpose parchment paper, which has already been employed for the same object by M. F. Carré.

I superpose several leaves of this paper in order to reduce the permeability, and I make my porous vessels in the form of a flat rectangular prism, so that relatively large surfaces can be given to the electrodes.

These prismatic vessels are obtained without cementing or a joint by the following method: in the middle of the leaf of parchment paper of which the vessel is to be constructed the base of the prism is sketched; on each of the sides of this polygon, and at a distance equal to the height of the vessel, parallel lines are traced, which together form a polygon larger than the one cut out. Finally, the vessel is formed by folding the portions of the septum placed outside the geometrical development of the prism. These folds are folded close one over the other, so that those faces of the vessel are made least permeable which are so required.

The zinc and the copper of the battery are cut out, without waste of the metal, from the ordinary commercial sheet zinc; the connecting lugs are formed out of the piece itself, which offers the double advantage of no soldering being required and of a passage for the circulation of the liquid being given. The copper is placed outside the porous vessel.

The initial electro-motive force of the ordinary zinc and copper couple, immersed in my solutions, is 1·47 volts. It falls to 1·35 volts after being on short circuit continually. The resistance is ·075 ohms

for the pattern here represented, the height of which is ·20 metres, and the capacity 3 litres.

In order to determine the rank which this battery should occupy in the series of couples with which it was compared, I have drawn up a list showing for each their electro-motive force, E, their internal resistance, R, and the *outside work done*, T, expressed in kilogrammes per second, this latter value being calculated by the expression:

$$T = \frac{E^2}{4R \times 9{\cdot}81}$$

By dividing the values in kilogramme metres by the mechanical equivalent of heat, the values of the work done can be obtained in calories (gramme degrees), which values are also given in the following table:

Name of Battery.	Constants.		Work.	
	E. In volts.	R. In ohms.	T. In kilometres.	T. In calories.
Bunsen: ordinary form; height, 20 metres, ...	1·80	·24	·344	·796
Bunsen: Ruhmkorff pattern; height, 20 metres, . .	1·80	·06	1·378	3·189
Daniell: round form; height 20 metres, ...	1·06	2·80	·010	·023
Daniell: Thomson's tray form; electrodes 12 decimetres sq.,	1·06	·20	·143	·331
Daniell: Carré pattern; height, 60 metres, . . .	1·06	·12	·238	·551
Reynier: rectangular form; height, 20 metres, . .	1·35	·075	·619	1·440

It can be seen that my new rectangular couple, ·20 metres in height, surpasses in power the largest sulphate of copper and sulphate of zinc batteries; it is about twice as powerful as the ordinary round Bunsen, and is only exceeded by the rectangular Bunsen, Ruhmkorff pattern. The zinc is not amalgamated, nevertheless it is not attacked on open circuit by the alkaline liquid in which it is immersed; consequently the weight of zinc consumed is perfectly proportional to the work done, and gives exactly the quantity of current generated.

The new battery, as has been before stated, does not emit any fumes, consequently it contains after work all the substances employed, altered in nature, but without loss. It is possible, therefore, to regenerate these products, that is to say, to bring them back again almost to their

original state. In order to do this, the exhausted liquids must be traversed by a quantity of electricity rather greater than that given out by the pile, by dissolving the copper deposited and depositing the zinc dissolved.

If magneto-electric machines are used for producing the electricity necessary to renew the battery, the renewal is done at the expense of motive power. Economically produced by the aid of powerful machines, the electricity becomes stored up in the liquids, regenerated to the state of energy which is disposable and portable. This indirect transport of electricity generated by machines would be, in most cases, more practicable and more advantageous than the direct transmission by cables.

Actually the renewed liquids are not employed, the new battery offering as it does a notable economy of material and labor over the nitric acid couples. As to the industrial realization of the process of regeneration, which should render my battery economically applicable to small electric motors and to domestic lighting, it is yet hindered by certain difficulties foreign to the art, which will, I trust, be overcome eventually.—*La Lumière Electrique.*

THE TEMPERATURE OF FLAMES.

From the paper of F. Rosetti,* in the *Annales de Chimie et de Physique,* we collate that his deductions from experiments with flames emitted by the ordinary gas burner, the Bunsen burner and the electric light, by means of a thermo-pile and a delicate reflecting galvanometer, gave the following results:

With the temperature of the air at 59° Fahr. (= 15°C.) the ultimate temperature of the blue flame at the outer edge of surface of a fantail burner was 2370° Fahr., while that of the interior white flame was 2100° Fahr. The average temperature of the flame he establishes at 2170° Fahr. It will be seen by referring to the article on Gas Engineering which was published in the JOURNAL OF THE FRANKLIN INSTITUTE in April, 1878, that the ultimate temperature of coal gas (based on the theoretic heat value of its constituents), when the products of combustion are taken to include the volume of air

* *Annales de Chimie et de Physique*, 5th series, vol. xviii, p. 457.

needed to effect complete combustion, is 2641° when the gas and air for combustion were taken at 70°.

The ultimate temperature of the flame of a Bunsen burner is given at 2280° Fahr.

The electric light gives as a maximum intensity of heat:

For the positive pole = 7050° Fahr.,
For the negative pole = 5700° Fahr. and
For the arc itself = 8700° Fahr.

There is still wanting an accurate measure of the *quantity* of heat emitted by the electric light to compare with the heat equivalent of the electro-motive force expended in the arc, and thus to eliminate the expenditure of heat in the production of light. B.

Book Notices.

An Elementary Treatise on Electric Batteries, from the French of Alfred Niaudet, translated by L. M. Fishback. 12mo. New York: John Wiley & Sons. 1880.

It is gratifying to examine a complete, thorough and yet pleasantly written and easily comprehensible text book, and this little treatise presents many qualities to entitle it to be considered a model of its kind. Its marked excellence is derived from the possession of full knowledge of the history and practice of the use of batteries by the author, beside that happy instructive ability which allows him to impart his information in fluent rather than precise language, suited to the casual and not alone the exact student. It is a recommendation that the treatise is divested from all consideration of electricity or electric force, except as pertaining to the battery, for by this singleness of presentation the detail of technical adaptation and of manipulation can be followed in all the forms of battery which have had the sanction of former or present usage. There has resulted a book at once suited to the reader of books, to the student in science and to the operative electrician as interesting, instructive and authoritative in the subject treated.

It must not be supposed that any book can fill the place of teacher to those most advanced in the art, and it is somewhat to be regretted that this treatise had not been "edited" to cover the last form or prac-

tice in the United States. A few pages well illustrated would have been very appropriate. And without desiring to find fault it might be well that next edition be more carefully proof-read, although the errors are mostly in letters (Fig. 10 of the illustrations should be Fig. 12). Two hours work would correct the chemical notations throughout. The book wants an index badly.

These minor defects do not detract from the immediate value of the work, which is an indispensable addition to the English library of every one interested in any way with electrical science. B.

ENGINEERS' AND MECHANICS' POCKET BOOK. By Chas. H. Haswell. 12mo. New York: Harper & Brothers. 1880.

During the past thirty-seven years this valuable work has been one of the most useful pocket reference books in use, and has now reached its 36th edition in an enlarged and revised form. The first edition of 284 pages was published in 1843 and intended to supply a long felt want of a convenient reference to Rules, Results and Tables, and has supplied that want to an extent beyond what was anticipated. In order to adapt it still more fully to the use of engineers and mechanics it has been gradually enlarged to embrace very general information upon arithmetical, physical and mechanical subjects; typographical and other errors have been corrected as far as noticed by the author or when his attention has been called to them, and every effort made to render the work a reliable one.

Space will only permit a brief reference to a few of the additions and corrections to the last edition. The article on "Animal Strength" has been much enlarged and brought up to the present year; the same with "Passages of Steamers and Sailing Vessels." Proportions of "Cements;" equivalents of old U. S. and metrical measures; dimensions and performance of pumping engines; "railroad speed;" "Miscellaneous notes" embracing solutions of questions by a graphic operation, matter, volumes, etc., have been added. The change of position of several articles has caused some errors in the index which, however, can readily be corrected. R.

CIVIL ENGINEER'S POCKET BOOK. By John C. Trautwine. New edition, revised and corrected. 12mo. Philadelphia: E. Claxton & Co. 1880

The fourteenth edition of this deservedly popular work is before

us. Originally written for civil engineers only, the vast amount of practical information condensed into it has made it equally a favorite with contractors, builders and machinists; beside leading to its adoption as a text book in many educational institutions.

Many new engineering facts are scattered throughout the volume; some subjects, such as "Cements and Concretes," "Rivets and Riveting," "Strength of Materials," "Iron" and "Wooden Pillars," "Trusses," "Railroads," etc., have been entirely rewritten or much altered; and those on "Buoyancy, Flotation, Metacenter," "Moments of Rupture and Resistance," "Kutter's Formula" for the mean velocity in feet per second in pipes, aqueducts, canals, rivers, "Open and Closed Beams," "The Shearing of Beams," "Test Borings," the valuable experimental results of C. Shaler Smith on "Eye Bars and Pins," "Velocities in Sewers," etc., are given for the first, time together with many new tables indespensible to engineers, builders and machinists.

The work is profusely illustrated with diagrams, explanatory of the most important formula, and the modern Engineer's Transit Instrument and Level as made by Heller and Brightly, Philadelphia, are now figured instead of the old-fashioned instruments, but we regret to notice, *without* their latest improvement—the Hoffman patent shifting tripod head.

Although the work was originally prepared specially for young members of the profession, it has been in most respects brought up to the present standard of civil engineering and experts will find it a most convenient work for ready reference, facilitated as it is by the improvement in the letter-press and insertion of much heavy black letter. R.

School and Industrial Hygiene. By D. F. Lincoln, M. D. 16mo. Philadelphia: Presley Blakiston. 1880.

This latest issue of the American Health Primers, so admirably edited by Dr. W. W. Keen, is in some respects the most important of the series, as it takes up school hygiene, in which so many thousands of parents in every large city are interested. In the chapter on the "Amount of Study," the author states that he does not believe the Kindergarten system injurious to a child of four years, unless carried to the point of over-excitement, which is not often done; but the common primary school is decidedly objectionable. It takes very young children, and compels them to remain twice as long as is good for

them. By great ingenuity and vivacity, a teacher can keep them upon various studies for three hours. This is all that is reasonably possible, yet the children are expected to come back for a second session in the afternoon. He concludes by stating that a school conducted by lessons and recitations—a mimic grammar school in fact—should not receive children under seven or eight years of age. The chapters on the "Care of the Eyes" and "School Desks and Seats" are very important; while the second part of the work takes up "Industrial Hygiene," and, after treating of the injurious effects of inhaling dust, poisonous substances, etc., the author treats of those from atmospheric changes, over-use of certain organs and accidents. Chapters on the regulation of hours of labor, and the duration of life in various occupations, are then given. A full index completes this very interesting little volume, which can hardly fail to be extensively read. N.

The Carpenter's Steel Square and its Uses. By Frederick T. Hodgson. Square 16mo. New York: Industrial Publication Co. 1880.

This little work consists of a republication of some papers contributed by its talented author some time ago to the *American Builder*, and which were received with so much favor by artisans, for whom they were written, as to induce their author to collect them into the present volume. It is not claimed that the rules and methods herein stated are original with him, but only that they have never been brought together before in so handy a volume. The work is well illustrated by upwards of fifty cuts which have been well engraved, and can hardly fail to give any one an idea of the capabilities of the steel square and what can be accomplished from it in skillful hands. N.

American Newspaper Directory. 8vo. New York: Geo. P. Rowell & Co., Publishers. 1880.

In this large volume of 1044 pages we have a complete list of the various newspapers and periodicals published in the United States and Canada, arranged alphabetically by States and places of publication, the population, location and prominent industries, etc., being also indicated. Such a list is exceedingly valuable, and as it is revised and printed every year must be up to date. Pains seem to be taken to make it as complete as possible, and the only fault that can be found with it is in the statement of the circulation of any publication, which after all, must be a matter of conjecture, except with the publisher. We know of no other work in which so much information on the above topics can be obtained. N.

Influence of Electricity on Vegetation.—In bamboos the flow of sap takes place at the beginning of the rainy season, but vigorous shoots rarely grow before the thunder-storms, which generally precede the harvest. The rapidity of their growth increases with the violence of the storm, amounting sometimes to as much as 70 feet in 30 days, the vegetation being most active during the night. Captain Sleeman suggests that the cause of this sudden growth may be the increase in the quantity of nitrogenous compounds, which are greedily absorbed by the humus that surrounds the roots of the bamboos. The facts offer a curious confirmation of the experiments of Dr. Siemens upon the influence of electricity on vegetation.—*Les Mondes.* C.

Boiler Scale.—M. Lodin has found that the predominant action upon boilers is due to the oxygen of the air which is dissolved in the water, and that this action, contrary to the general opinion, is slightly greater with calcareous waters than with distilled water. A second cause of oxidation, of much less importance, is the decomposition of the water by the iron. This also is a minimum with pure water. The scale deposits can only adhere to a surface in which oxidation has commenced, and the most efficient disencrustants, such as zinc, are those which prevent the oxidation of the boiler plates. Campeachy wood, potato starch, and some other ingredients, owe whatever efficiency they possess to the formation of compounds with the oxide of iron, which have little adhesive power, and can therefore be easily removed.—*Comptes Rendus.* C.

Electro-Dynamic Paradox.—M. Gérard-Lescuyer has discovered a novel phenomenon, by sending the current produced by a dynamo-electric machine into a magneto-electric machine. As soon as the circuit is closed the magneto-electric machine begins to move; it tends to take a velocity proportioned to the intensity of the originating currents, but it soon moves more slowly, stops, and turns in the opposite direction, going through a similar series of changes and returning to the first direction. This regular alternation of movement continues as long as the originating current is in action. In trying the experiments a Siemen's dynamo-electric machine, with continuous currents, was used as the generator. The receiver was a small laboratory Gramme machine, with an ordinary permanent magnet, constructed by M. Breguet.—*Comptes Rendus.* C.

Decomposition of Carbonic Anhydride by Magnesium.—Upon plunging a fine burning wire of magnesium into a large glass cylinder filled with carbonic acid, the metal continues to burn with a brilliant white light and to throw out brilliant sparks in all directions. Carbon is soon deposited upon the walls of the cylinder, while the heavier magnesia falls to the bottom of the vessel. The phenomenon forms a very interesting lecture experiment.—*Polyt. Notizbl.* C.

Celluloid Stereotypes.—Emile Jeannin, a French sculptor, being impressed by the malleability of celluloid at 125° C. (257° F.) thought of using it for stereotype plates. The electrotypes from wood engravings require long and complicated operations. The plates which are made from celluloid can be prepared in half an hour, and they are very sharp, very strong, very light and very flexible, so that they can be successfully, readily and usefully applied to the surface of the cylinders of fast presses.—*Les Mondes.* C.

False Meteorites.—In the collection of meteorites which M. Daubrée is making he is obliged frequently to decide upon the authenticity of specimens which are forwarded to him. Some of them come from men of distinguished scientific ability and accustomed to observation, such as Le Verrier, Becquerel, Antoine Passy, Marshal, Vaillant, and yet the collectors are deceived in spite of their skill. There are various reasons for this deception. The luminous and acoustic effects of lightning, in some cases, may be confounded with the explosion of bolides, and it is natural that a stone picked up in the neighborhood of a point where the meteor seemed to fall, should be taken, if it is different from the neighboring rocks, for a mass fallen from the sky. The mistake is the more easy because, by an inevitable illusion, one always seems to be near the point of fall, even when he is miles away from it. This remark is especially applicable in the case of a bolide, or of a shooting star, which is followed by a luminous train, and which seems to fall vertically upon the ground. Sometimes, in cretaceous districts, balls of radiating pyrites are found, which are so changed by disaggregation as to differ completely in appearance from the ordinary rocks. In consequence of these frequent errors Daubrée urges the importance of caution in accepting any statements about the fall of bodies until specimens have been carefully examined.—*Comptes Rendus.* C.

Electric Fishing.—An electric fish-hook has excited much attention and curiosity at the Berlin exposition. It is attached to a little skiff, which can be directed noiselessly towards any point of the water by means of a helix and wheel work. When reaching the desired location it anchors itself against wind and stream while the line and hook glide into the water. The skiff contains an electric battery and an induction coil, so arranged that the slightest bite completes the electric circuit. Immediately, with the rapidity of a flash, under the action of an electro-magnet, the line, hook and fish are raised into the air; a little bell rings to inform the fisherman of the capture, so that he can draw the skiff ashore and detach the fish.—*Les Mondes.* C.

Contact Electricity.—F. Exner attributes the electricity which is developed by the contact of two metals to the difference of the chemical actions of the surrounding medium upon the metals, and he thinks that the quantities of electricity are proportional to the heats of oxidation, as in hydro-electric couples.. The experiments of De la Rive show that there is no charge in a vacuum or an inert gas, moreover, the orders of oxidation and of electric tension in the air are identical. The heats of combustion are well known, but there is a great divergence between the values which have been given to electric tensions by different authors. Exner employs a new condenser to measure them, and finds a remarkable accordance between the observed and calculated values. The chemical theory accounts readily for all the observed effects, but the contact theory is insufficient in many cases.—*Wied. Ann.* C.

Franklin Institute.

Hall of the Institute, September 15th, 1880.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

There were present 86 members and 15 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that 26 persons were elected members of the Institute at he July meeting and 12 at the August one.

The Secretary reported the following donations to the Library:

Eleventh Annual Report of the U. S. G. and G. Survey of Territories for 1877. By F. V. Hayden. From the Author.

Council Book of the Corporation of Youghal from 1610–1800. By R. Caulfield. Surrey, 1878. From the Author.

Annales of Astronomical Observatory of Harvard College. Vol. 12. By W. A. Rogers. Cambridge, 1880.

Catalogue of 618 Stars, observed at Astron. Observatory of Harvard College. By W. A. Rogers. Cambridge, 1880.

Contributions to our Knowledge of the Meteorology of the Artic Regions. Part 2. London, 1880.

Meteorological Observations at Stations of Second Order for year 1878. London, 1880.

From the Meteorological Committee of the Royal Society.

Report of the U. S. Survey of the Territories. F. V. Hayden in charge. Vol. 12. Fresh Water Rhizopods of North America. By Dr. Jos. Leidy. Wash. Gov't, 1879.

From Dr. F. V. Hayden.

Astronomical Papers prepared for use of American Ephemeris and Nautical Almanac. Vol. 1, Part 2. Wash. Gov't, 1880.

From Bureau of Navigation, Navy Dep't, U. S.

Memoirs of Geol. Survey of India. Palaeontologia Indica. Ser. 14, Vol. 1, Part 1. Calcutta Gov't, 1880. From the Survey.

Smithsonian Miscellaneous Collections. Vols. 16 and 17. Washington, Inst., 1880.

Smithsonian Contributions to Knowledge. Vol. 22. Wash., Inst., 1880. From the Institution.

Report upon U. S. G. Surveys west of 100th Meridian. Vols. 2, 4 and 6. From Lieut. G. M. Wheeler.

Report of the Supt. of U. S. Coast Survey for 1876. Wash. Gov't, 1879. From the Survey.

Report of Department of Public Works of New York City. Mar. 31, 1880. From the Department.

Proceedings of 28th Meeting of Board of Supervising Inspectors of Steam Vessels. Wash. Gov't, 1880 From the Board.

Iron and Steel Works of the United States for 1880.

From the Iron and Steel Association, Philadelphia.

Fifty-first Annual Report of the Board of Commissioners of Public Schools. Baltimore, 1879. From the Commissioners.

First Annual Report of the Department of Statistics and Geology of Indiana. 1879. From John Collet, Chief of Bureau.

History of Bunker Hill Monument Association during 1st Century of United States of America. By G. W. Warren. Boston, 1877. From the Association.

Catalogue of Trees and Shrubs in Horticultural Hall Gardens, Fairmount Park. From the Horticultural Society.

Thirteenth Annual Report of the Peabody Institute of Baltimore, 1880. From the Institute.

Catalogue of the Library of the Geological Society of London. 1880. From the Society.

List of Vertebrated Animals in the Gardens of the Zoological Society of London. 1879. From the Society.

Microscopists' Annual for 1879.
From Industrial Pub. Co., New York.

Indian Meteorological Memoirs. Vol. 1, Parts 3 and 4.
Report of Administration of the Meteorological Department of the Gov't of India in 1878 and 1879.
From Meteorol. Reporter of Gov't of India.

Testimony at Coroner's Inquest ot St. Charles Bridge Disaster of November 8th, 1869. By S. H. Younge. From the Author.

Report on Plans for Warming and Ventilating Bridgeport Schoolhouse. By R. Briggs. From the Author.

Circulars and Pamphlets pertaining to Exhibitions.
From L. S. Ware.

Annual Report of Chief of Engineers, War. Dept., 1879. Wash. Gov't, 1880. 3 Parts. From Chief of Engineers.

First Annual Report of the State Board of Health, etc., of Massachusetts, 1879. Boston, 1880. From the Board.

Annual Reports of the Inspectors of Mines of the Anthracite Coal Regions of Penna. for 1878 and 1879.
From the Inspectors of Mines.

Annual Report of the Board of Regents of Smithsonian Institution for 1878. From the Institution.

Annual Report of the Commissioner of the General Land Office for the fiscal year ending June 30th, 1879. From the Commissioner.

Annual Report of the Chief Signal Officer to the Secretary of War for the year 1879. From the Secretary.

Industrial Progress in Gold Mining. By G. W. Baker.
From the Author.

Circulars of Information of the Bureau of Education. Nos. 2 and 3. 1880. From the Commissioner.

Patent Office Reports. Agriculture, 1854–1856 and 1858 and '59. Mechanics. Vols. 1 and 2. 1855.

Catalogue of British Section of the International Exhibition. Philadelphia. 1876.

Catalogue of Chinese Imperial Maritime Customs Collection at U. S. International Exhibition. Philadelphia, 1876.

Der Buchhandel und die graphischen Künste Deutschlands auf der Weltausstellung zu Philadelphia, 1876.

Catalog de los Expositores de España. Philadelphia, 1876.

International Exhibition, 1876. Official Catalogue. Dept. 4.

Œuvres d'Art et Produit Industrielles de France.

Mortality Statistics of the Census of 1850.

From Dr. Carl Hering, Philadelphia.

Speeches and Forensic Arguments. By D. Webster. Boston, 1880.

Journal of Franklin Institute, 1837 and 1838.

The Bible in Spain. G. Burrow. 1843.

Patent Office Reports, 1851 and 1852.

Diplomatic and Official Papers of Daniel Webster. 1848.

Elements of Surveying. C. Davies. 1836.

Treatise on the Principal Mathematical Instruments. By F. W. Summs.

Life of Galileo. 1835. From B. B. McKinley.

Second Treatise on Decrease of Water in Springs, Creeks and Rivers. From Chief of Engineers, U. S. A.

Mr. Tatham announced that a life-size crayon portrait of the late Secretary, Mr. J. B. Knight had been made during the summer, and he would be pleased to hear from any one on the subject.

Mr. J. Snowden Bell offered the following resolutions which were adopted unanimously:

WHEREAS, We, the members of the Franklin Institute, have heard, with great pleasure, that this institution has been presented with a portrait of its late Secretary, Mr. J. B. Knight, therefore be it

Resolved, That we receive with thanks this pleasing memorial of Mr. Knight.

Resolved, That we hereby request the proper authorities of the Institute to place this gift in some prominent position in the rooms of the Institute, as a fitting tribute of respect to the memory of one who so earnestly labored in behalf of the purposes of this institution.

Mr. W. Barnet Le Van read a paper, illustrated by diagrams and drawings, on "The Weakening of Steam Boilers by cutting holes in the shell for domes and necks." He said that the weakening effect of cutting holes for domes or necks was proportioned to the section of the

dome joining the shell, independent of the size of the hole cut, and expressed the opinion that domes should be discarded and boilers of slightly larger diameter, with perforated tubes, used, instead of boilers with domes. He cited instances of the successful use of locomotive and stationary boilers constructed without domes. He contended that manholes should never be cut in the shell if it was possible to avoid doing so, and described at length experiments made by the Manchester Steam Users' Association in 1876, in support of his statements. He referred to the bad record made by the "two-story," or "Rider" boilers, such as exploded in Cherry street in 1864, and the one at Wilt & Sons' mills, which burst last year. He considered the form dangerous, and doubted whether it was as economical as had been claimed, and also said that "outside of a radius of thirty miles of this city they are scarcely known." The boilers tested by the Manchester Steam Users' Association were analogous in construction to the "two-story," or "Rider" boilers.

The diagram of a boiler containing the perforated pipe suggested by Mr. Le Van was thrown upon the screen, and some discussion arose as to the proper position of the pipes as shown in the diagram, in which Messrs. Cooper, Nystrom, Bell, Cartwright and Le Van participated.

Mr. Bell called attention to an inaccuracy in the paper read by Mr. Le Van, which he had seen mentioned elsewhere, and that was in regard to the use some years ago on the Baltimore and Ohio Railroad of locomotives without steam domes. He had been connected with the road at the time mentioned (from 1860 to 1865), and they had at the time eight Mason engines, all of which had steam domes.

Mr. Le Van said that there were some roads in England successfully using locomotives without steam domes.

Mr. Orr, referring to a statement in Mr. Le Van's paper about a boiler which was being tested, and which, after standing a pressure of 149 pounds, burst at the addition of another pound, expressed the opinion that a safe limit of test should be adopted to prevent such explosions.

Dr. Seiler exhibited and described a photophone, in which a ray of light, passing through perforations in a revolving disk, and being thus interrupted, transmitted a sound proportioned to the velocity of the disk, to any substance except carbon or fine glass. He also gave an account of Prof. Bell's experiments which led to the invention of the

photophone. Selenium, in its crystalline form, when exposed to light, opposes less resistance to the passage of an electric current than when in darkness. Prof. Bell made a cell of selenium, and introduced it in the primary coil of an induction coil, the secondary coil being connected with a telephone. He then took a disk of silvered mica, condensed on it the sunlight, and throwing the reflected light, condensed by a lens, upon the selenium cell, made the beam of light and interrupted one by speaking against the mica disk, and setting up vibrations, which changed its form. The varying resistances offered by the selenium to the passage of the current resulted in movements of the disk of the telephone in circuit therewith, corresponding with the variations produced by speaking against the mica disk at the other end of the beam of light. The photophone had been tried at a distance of 900 feet—far enough apart to make it certain that the voice of the speaker could not be heard without the use of the photophone—and conversation had been successfully carried on. Dr. Seiler said that he had had satisfactory experiments with it over a distance of about sixty feet. He considered it an instrument of extreme scientific interest, but did not know whether it would be of any practical value. The medium of transmission is not heat, nor light in conjunction with heat, for an alum cell has been used to cut off the heat rays. In the simple instrument which he exhibited one could hear the sound of the interrupted beam of light without the use of the diaphragm, and that the sound was not an imaginary one could easily be tested by putting the hand in the beam of light, thus interrupting the sound.

Mr. Cooper inquired why, with a mechanical arrangement of this kind, carbon or glass could not be used.

Dr. Seiler replied that very little was known as yet about this new instrument. There are many obscure facts about its operation. All that observers can now do is to report facts as they find them, and it appears from experiments that some substances are better than others. He would not say that glass or carbon would not respond by sound to the interruptions of the beam of light, but only that they were not as good as some other substances—hard rubber for instance.

Prof. Houston said that this was one of the most wonderful discoveries ever made. He had not had the advantage of seeing the experiments described in the garbled reports of newspapers, but he nevertheless felt competent to make a photophone from what he knew about the principles on which they are constructed. They may be aptly

described as telephones without wires, the beam of light being, so to speak, the connecting wire. Some day, perhaps, we shall have the navigator getting into the beam of the lamp of a lighthouse, and, instead of looking at his chart, calling along the beam to inquire, "What lighthouse is that?" He again described the action of the photophone, with the aid of a diagram on the background, saying: Here you have a battery in the circuit of which more or less current flows according to the resistance. You put selenium in the circuit, and the resistance varies with the ray of light that falls on it. You put a telephone in the circuit, and the movement in the plate corresponds with the varying strength of the current. The most remarkable part of the discovery he considered to be the fact that cutting off the heat rays by an alum cell, and cutting off the light by a plate of rubber, yet something passed through which the interruptions of the light were made manifest by sound. There was something in this which suggested the fourth state of matter, for the illustration of which he saw some apparatus on the table.

Mr. Walton, of James W. Queen & Co., exhibited Prof. Crookes' Tubes, now manufactured and sold by dealers in philosophical apparatus. These tubes are exhausted to about the millionth of an atmosphere, and this high vacuum has been supposed to present a *fourth* state of matter—something beyond the gaseous—and where matter behaves in an entirely different manner from anything heretofore known.

Mr. Crookes says that in this fourth state of matter we have actually touched the border land where matter and force seem to merge into one another.

Mr. Walton exhibited the "stencil tube," showing the shadow of a cross in the radiant matter, the "railway tube" showing the mechanical action of radiant matter, the electric-radiometer, etc.

A resolution was adopted inviting Mr. Outerbridge to lecture on the subject during the winter.

Among the novelties exhibited were Evans' Mercury Seal and Sewer Gas Trap, Wentworth's Saw Vise, Holt's Can Opener, McAlpin's Portable Oven and Grant's Revolving Water Filter. In this filter the globe containing charcoal, through which the water passes, can be turned upside down, so as to be readily cleaned of impurities.

On motion, the Institute adjourned.

Isaac Norris, M. D., *Secretary*.

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THE METRIC SYSTEM — IS IT WISE TO INTRODUCE IT INTO OUR MACHINE SHOPS?

BY COLEMAN SELLERS, M.E.

Read before the American Society of Mechanical Engineers, Nov. 4, 1880.

The organization of a Society of Mechanical Engineers offers a convenient and fitting opportunity for the presentation of the views of a mechanical engineer on the subject of the metric system to members of his own profession and to those who are similarly interested. During the month of May, 1874, I had the honor of reading before the American Railway Master Mechanics' Association a paper on "The Metric System in our Workshop; will its value in practice be an equivalent for the cost of its introduction?" In that paper I treated the subject mainly in reference to its cost. From what has since been published by those who advocate the enforced substitution of the metric system for the weights and measures in common use in this country, it is evident that the subject will bear to advantage a different treatment. I now propose to supplement the question of cost by an endeavor to show that the system, *per se*, is not so well adapted to the wants of machinists as is the one now in use, and that its enforced introduction will do harm to our industries in place of doing good.

In addressing to the members of the American Society of Mechani-

cal Engineers arguments in opposition to any compulsory legislation in this direction, I feel that I am speaking to men who are familiar with the subject and who have already given thought to the results likely to obtain from the proposed change in the system. I feel, too, that I am speaking to those whose habit of thought fits them to consider the subject without bias; mechanical engineers, of all men using weights and measures, are the ones most eager to adopt what in the end will be of the most use. To them weights and measures are not abstract ideas, but tangible substances. Engineers make the machines for weighing and measuring, and the result of their use of those machines exists as fixed matter, costing millions upon millions of dollars.

To the great bulk of mankind engaged in trade, in buying and selling, in bartering and exchanging, it matters little what system they adopt; it matters little whether they are obliged to use a yard-stick or a metre-rod, pounds or kilogrammes, quarts or litres. The cost to them of a change from one to the other is the cost of the few devices needed in weighing and measuring; the *rationale* of the system may never enter their thoughts.

With the machinist the case is different. He must not only possess costly means of measuring and weighing, with a degree of exactness unknown to others, but the results of these weights and measurements are fixed and unalterable. Enormous expenditures on tools, on drawings, on patterns, on everything he uses in making or building his machines are on what is involved in the primary system used in determining weight and size. The product of this expenditure means everything that makes modern civilization possible. I propose, in this paper, to consider the subject only as it relates to our own profession; not in regard to its effect on the grocer, the dry goods man, or on the druggist. I propose to show why, after nearly twenty years' constant use of the metric system of measurement, I record my opposition to any enforcing legislation in this direction, because *the metric system is not well adapted to the practice of the machine shop.*

To render my arguments of any value I must endeavor to express myself so as to be understood by those who are not mechanics, and must crave the indulgence of my associates for dwelling, as I shall have to, on details so familiar to them and for making my explanation of the usages of the workshop so elementary.

For nearly twenty years one large department of Wm. Sellers &

Co.'s establishment has been worked on the metric system, as thoroughly as the system can be worked in any machine shop; as thoroughly as it is worked in France or Germany. The drawings made for this department are to the metric scale, figured in millimetres. The small tools and gauges are to metric measurement only, and the product of the shop is scaled to metric sizes and called by names based on those sizes.

During all these years, and for many years before, we have taken pains to inform ourselves, so far as lay in our power, as to all possible good to be derived from the system, in the drawing room as well as in the shop. We inquired into its defects and endeavored to overcome them by the same means as are resorted to in metric using countries. The system is urged by theorists as a perfect system. All nations, we are told, should adopt it to bring about a desirable unity in weights and measures, even if all cannot be made to speak our language and all cannot be equally good and pious, as measured by some international scale of goodness and piety.

The metric system was legalized here in May, 1866. Some of its enthusiastic advocates now urge its being made exclusive and obligatory. Societies are organized to teach its principles to the people, and much money has been expended in publishing, but up to this time few conveniences have been placed in the hands of mechanics to enable them to use it in their calculations. Some years ago (the conditions remain the same to-day) letters addressed to leading publishing houses asking for metric books in the English language, equivalent to those to which we constantly refer, which books are as necessary to us as are our other tools, failed to bring a single favorable answer. What was asked for, was some book in which formulæ shall be given in the most convenient form expressable in relation to the metric nomenclature. Many books can be found urging its merits as a system, and the writers of these, in showing (?) that the metric system can be learned entire in say fifteen minutes, may think they have done what is needed, but no book yet published in the English language, so far as I have been able to learn, even approximates to what is required. We have nothing like the hand-books published in German. These Germans, in teaching their people, gave side by side in these almanacs of mechanics the formulæ expressed in Prussian inches and in metres. When the year 1880 came around they dropped the Prussian inch from these books when it was possible so to do. There are many

very good books of tables for the ready conversion of the measurements of one system into the other, but unless an engineer is as familiar with the metric system as with his own they aid him but little. On the other hand, our English work books are many and valuable. The great bulk of literature of primary importance to mechanical engineers is in English and expressed in feet and in inches.

The absence of these help books need not, however, prevent any one *familiar with the metric system* from using it in his practice. If he can think in the new system he can work in it too. He can formulate what is directly needful to him if he will take the time and trouble so to do. The absence of these books has not prevented us from using it or familiarizing ourselves with it, and had it proved worth the effort, and possible, we would long ago have placed ourselves in position to advocate it, as none can knowingly do who have not tried it. In designing any engineering work, proportioned structures can be produced by either scale; the working drawings can be then made to whatever system obtains in the shop of erection. This change from one or the other system in the drawing room is a matter of no difficulty whatever. The change from one system to the other in the workshop, however, involves more than the usual advocates conceive of.

To show the measure of the misapprehensions as regards its effect on our profession, on the part of the enthusiastic advocates of the exclusive metric system, I will pass by some lesser lights and seek illumination from the central luminary.

Mr. Frederick A. P. Barnard, S.T.D., LL.D., who, besides being President of Columbia College, in New York City, is also President of the American Metric Bureau, and of the American Metrological Society, etc., etc., said, Dec. 27, 1877: "It is now little more than a dozen years since the movement in favor of the reform of the confused metrological system of the United States was set on foot. Originating with a few *advanced thinkers*" (the italics are mine) "and regarded with indifference by the multitude, it encountered, as it is the fate of all efforts to emancipate mankind from the burden of traditional evils, to encounter a much larger degree of opposition than of encouragement or favor." Then, after denouncing many of those who oppose the forced introduction of the system (see page 279 and elsewhere in his Metric System) says on page 283 of the same book, "Among the arguments urged by those who maintain the impossi-

bility of change only one appears to have much force, and that is the argument drawn from the dependency of machinery upon minute exactness in the measurements of parts and from the great expense which would attend the adaptation of machine shops and machines to a new system." Quoting the majority report of the Franklin Institute as to probable cost, and referring to the second report of the committee of the New York University Convocation, in which report the number of dimensions requiring separate indications on the drawings of a twenty-five-horse-power steam engine are given, he continues: "Singularly enough these statements, and all the rest of the same class in both the reports referred to, instead of being arguments against the abolition of the present metrological system and the substitution of the metric for it, afford the strongest reason for believing that that is precisely the thing which ought to be done. We desire, I suppose, to create a demand for our steam engines and our manufacturing machinery on the continent of Europe." "But a steam engine or a machine, all of whose parts are measured in English linear measures, if transferred to a metric country and there, by accident, disabled, becomes nearly useless, *since the shops of such a country afford no facilities for repairing it*," etc. (the italics again my own).

It seems needless to tell engineers that these statements show so entire an ignorance on the part of Mr. Barnard of the merits of the case as can scarce be credited from such a source. I feel ashamed to tender to him an explanation of what is involved.

The unit of measurement used in making a machine does not in any way complicate the repairs of that machine. Machines built in England do not always agree with any of our even sizes, yet this discrepancy is a matter of no moment in the repairs of any of them. If we fail to find sizes corresponding to our sizes in English machines, presumably built on the same scale of linear measurement as are our own, neither do we find even millimetre sizes, always, in machines from France or Germany.

Wm. Sellers & Co. make injectors for feeding boilers. They make them to the metric scale. They were doing so some years before Mr. Barnard's "few advanced thinkers" went into the metrological reform business. Their instruments are made from drawings figured in millimetres in all parts, except where screws and screw threads are needed. Screws to be cut on existing lathes cannot be conveniently figured

metrically, unless we adopt the custom of some German shops to figure in one dimension and make gauges to some other one. A screw bolt in Germany called 25 mm. diameter must be made 25·4 mm. size to conform to the screw system in use there; it will have 8 threads per inch and consequently 8 threads per diameter (I will explain this later). Screws cannot be metrically divided until metrically divided lead screws have been originated and put in the place of the inch divided lead screws *common to all lathes in all parts of the world.*

The people into whose hands these injectors pass know nothing of the scale of proportions to which they have been made. If some piece needs repairs and its shape has been lost by wear, it is needless to say that a knowledge of the scale would give no clue to that shape, but from some existing original any part can be copied; to copy requires no knowledge of the scale used. Repairs, too, as a rule, require deviation from original size to compensate for wear.

While the value of the unit of measurement may be of little moment in repairs, it is, however, all important in the first production of machines. This leads me to another misunderstanding on the part of those whom Mr. Barnard classes, I presume, with his advanced thinkers; this cleared away will bring us to the positian required in a judicious consideration of the two systems in their application to the machine industries of our country. I quote now from a pamphlet by Mr. Persifor Frazer; this pamphlet, says one of the Metric-Bureau tracts "contains more points, all well made, than any other of the same size on the subject." One of "the points" was suggested to him by the reading of a manuscript paper on the subject, said to have been written by an American engineer. The point made is this: "Lengths, breadths, thicknesses, capacities, and weights of things are related to the accomplishment of man's purposes and are varied to conformity with the inflexible laws of mechanics for different motors, strains, and materials; no change of system will alter in the least their dimensions, though it may give them different names." * * * "The grand truth of mechanics is, that the properties or dimensions of parts of machinery to accomplish any given purpose will be unaffected by any standard of length or weight applied to the part." This is a very good point, sounds well, but as the facts are not *exactly* as stated the point, is a dull one. No workshop in the land is or can be equipped with minor tools and gauges for the production of all sizes by *infinite* gradations. The calculated proportions of machines, the sizes indi-

cated by "the inflexible laws of mechanics," are sizes which must be made to conform to the nearest existing means of production and the merchantable sizes of the matter to be worked into shape.

In shop practice and in mercantile practice, to avoid an endless variety and confusion of sizes, certain dimensions in progressive order are adopted, being the sizes found most useful and most *salable* in practice. These progressive sizes we may call, in order to make the matter easily understood by "advanced thinkers" *Shop sizes* and *Merchant sizes*.

It is by the use of well considered ranges of shop and merchant sizes that the maximum of convenience is obtained at the minimum of cost. Hence one metrological system may be found to possess advantages over another when put to the test of practice. The one that is best in affording the most convenient and the most easily used and *memorized* series of sizes should not be called unphilosophical.

The resting place for memory in the American series of shop sizes is the inch. The inch is subdivided by a process of repeated halving down to $\frac{1}{16}$ in the usual grade of shop and merchant sizes, as in bar iron. This gives 16 sizes to the inch for small sizes; 8, 4, 2 or 1 to the larger sizes.

If a machinist should order from us a set of caliper gauges from $\frac{1}{8}$ up to 2, advancing by $\frac{1}{16}$, and from 2 up to 4 advancing by $\frac{1}{8}$, we are at once informed of the shop system contemplated in his workshop.

Calculations based on the "inflexible law of mechanics," as read by *finite man*, intimates for the size of a certain part of some machine a dimension 3·95 inches diameter, the prudent engineer has possibly assumed a sufficiently ample *factor of safety* to permit him to select $3\frac{15}{16}$ inches, the nearest shop size below the theoretical size, $3\frac{15}{16} = 3{\cdot}9375$ inches. He desires to use this shop size, because 4 inch iron, an obtainable merchant size of bar iron, will clean up from the black to this size; but if his dimension relates to castings or forgings he may select 4 inches as a shade stronger.

Metric using people have ranges of shop and merchant sizes too; when I come to compare their possible series and their actual series with our own some faint glimmer may come to those who now know nothing about the matter of the fact that our unphilosophic system is not so very bad after all.

In regard to what is involved in each shop size, in a money point of

view, I will give but one single example. The inquiry to our own tool-room keepers for a list of the separate devices used in producing one size, viz. $1\frac{1}{4}$ inch, brings to me the names of 129 articles or sets of articles, such as drills, reamers, gauges, boring bars and cutters, taps of all kinds for all sorts of uses, hardened mandrels, etc. etc. These many pieces, costing many hundred dollars, represent one size only. They tally with and belong to the dimension marked $1\frac{1}{4}$ in many thousand places on drawings, which have been accumulating for years, to patterns loading down our pattern lofts, to gear wheels interchangable over a continent, and to the out-put of our factory for years. So important in an economical point of view has come to be these shop size series, that machines built in one shop, if to be reproduced (not repaired) in another, must be redrawn to conformity to the shop system in use before the work can be begun to advantage. Year by year this harmony in shop sizes in America spreads over a larger area. Entire harmony in essential points exists in many of the leading shops. There are, however, examples still to be found in which machines built in one shop have no dimension in common with the shop sizes we use, as compared to our inch series or our millimetre series, *for we use both.* The expert recognizes such machines as having been built to gauges varied by the judgment of the master workman, or by the more *costly* method of fitting one piece to another already completed, a process not admissible in any well regulated machine shop.

A good workman may by hand construct, we will instance, a sewing machine. He will alter and try, and rearrange its parts until he has satisfied himself with the result. He may not have scaled this machine to any system. It goes to the manufacturer who must per force change some of the wild-cat sizes to conform to merchant sizes of the material to be used. For the rest he may be content to fit gauges and templates to the model and reproduce it in minute exactness. We recognize, however, in every well arranged series of shop sizes, and in the means employed to *maintain size*, the highest value of possible *merchantable* good workmanship, for in such possibilities we recognize economy in tools as well as in work, in interest on capital and in wages. This system has been growing year by year in spite of our so-called unphilosophic metrology. Eli Whitney, in 1798, gave a lesson in this direction when he began to make muskets with interchangeable parts in Springfield, Massachusetts, but it was not until 1855 that the English Government recognized what Whitney had

done by importing American gun-making machinery. Since Whitney's time, the standard system has been carried into all branches, not only of our own trade, but into all the requirements of other trades as well.

The metrology of the American shops is based on the inch, and on it only. This dimension is cut up into minor parts by halving to any degree of subdivision, practically in shop sizes to $\frac{1}{64}$; it is also divided into 10 parts and into 12 parts when such divisions serve any good end. All such divisions have their uses and lead to no confusion. The inch squared is the base of our strains and pressures. The inch cubed gives us capacities. Later, I will speak of 12 and 36 inches squared and cubed. This one unit, the inch and pound weight of 7000 grains Troy, is all that a machinist needs to carry on his business. His inch is the same inch as is used in England and in the Russian machine shops. His pound is the pound in common use in England.

In America we have dropped some needless weights and measures, just as we have seen fit to drop the letter u from some of our words. We do not use in the machine shop the ton of 2240 pounds nor its quarter or its hundred weight; we do use a weight called "ton of 2000 pounds." This is the factor weight in strains, and by it we sell machinery. Other trades may retain some of these useless things; I am speaking only of machine shop practice.

The unit of measurement in France and in Germany is the *millimetre*. It is not and cannot be the metre for the following reason: The great majority of all sizes used in the construction of any machine, whether it be big or little, are less than one metre. By the use of the millimetre only, decimals are avoided. 8 millimetres must be written 8 in the millimetre scale, while it must be written ·008 in the metric scale. This is reason enough, for by the use of millimetres only, confusion of signs is avoided, and the *danger incident to decimals* is also avoided, hence *all* drawings are figured in millimetres only, up to dimensions measuring many thousand millimetres. This little dimension is then squared and cubed, or ten or a hundred millimetres are squared and cubed, for the uses corresponding to our squared and cubed inch and foot. As may be expected, happy coincidences of convenience are found in either system. Thus an ardent metric advocate instances that 1 kilo to the square centimetre is just one atmosphere. We say 15 pounds to the inch is an atmosphere. Neither one is right, but the 15 pounds to the inch is 1 per cent. nearer right than the other is.

For a machinist who seldom uses atmospheres a happy coincidence on the other side will be of more service. It so happens that wrought iron bars with parallel sides measure in square inches of this section just one-tenth of their weight in pounds per yard. Now, inasmuch as "shapes" in iron are rated by the pounds per yard, for convenience in large structures, so it comes to pass that, when we know the weight per yard of any wrought iron "shape," we know at once its sectional area. In as much as compression and extension and factors of safety are involved in a knowledge of cross section it is handy to be able to find it so readily, is it not? A shape iron, 80 pounds to the yard, has 8 square inches area of section. If it is good for 10,000 per square inch in extension we may load it with 80,000 pounds.

I have set out to compare the two scales—to compare the two units, rather, after an experience of twenty years with both. The inch is 25·4 times larger than the millimetre. These are the two dimensions we are to compare.

We will begin in the drawing room. Here "the inflexible laws of mechanics" find their first expression in form on paper. Few machines, or even parts of machines, can be drawn full size. Hence comes the need of "scales." There is reason in all things, even in scales. The unwritten law of most machine shops is to make every drawing as large as possible, as near full size as the nature of the subject and the dimensions of the paper used will permit. We have in our drawing room about 125 drawers, each of which will take in, without folding, drawings 52 inches (1320 mm.) long by 33 inches (840 mm.) wide. This is about as large a sheet as we can use to advantage, and tracings from these are not unmanageable in the work shop.

For metrical drawings we can use the following scales *only:*

Full size in which	1 mm. = 1 mm.
One-half size in which	½ mm. = 1 mm.
One-fifth " "	2 mm. = 1 cm. or 2 cm. = 1 dm.
One-tenth " "	1 mm. = 1 cm. or 1 cm. = 1 dm.
One-twentieth size in which	5 mm. = 1 dm.
One-twenty-fifth size in which	4 mm. = 1 dm.
One-fiftieth " "	2 mm. = 1 dm.

Down to the one-tenth scale the dimensions can be read from a good millimetre rule, for the one-twentieth, the one-twenty-fifth and the one-fiftieth scales must be constructed. The jump from one-half to one-fifth size is unfortunate. Could we conveniently quarter the

whole size we would have an increased area section, a matter of much moment. The $\frac{1}{2}$ of 10 inches is 2 inches, and the square of 2 is 4. The $\frac{1}{4}$ of 10 inches is $2\frac{1}{2}$ and its square is $6\frac{1}{4}$, a gain in size of over 50 per cent; a gain in comfort, in convenience and in eyesight. Here we catch the first glimpse of the advantage of our own system: for with it draughtsman can, from an ordinary well-divided inch rule, obtain the following scales: Full $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{8}$, $\frac{1}{12}$, $\frac{1}{16}$, $\frac{1}{24}$, $\frac{1}{32}$, $\frac{1}{48}$, $\frac{1}{64}$—12 gradations, as compared to 7, and to these 12 can be added with perfect ease 5 of the others, making 17 in all, if the preference be for the decimally divided inch, a scale carried in the tool box of every machinist, and obtainable from the two-foot rule in so common use.

The scale series in most common use is that of $\frac{1}{2}$, $\frac{1}{4}$ and $\frac{1}{8}$; this halves down from whole size and can be raised, in rapid drawing, by taking off diameter sizes from one drawing and using them as radius-dimensions in the other, a process impossible between $\frac{1}{2}$ and $\frac{1}{3}$ sizes.

The true value of this extended series of scales, with its peculiar advantages, is manifest to any one familiar with both, *and admits of no dispute*. Is it a wonder that draughtsmen brought up under a metric rule take so kindly as they do to our unphilosophical system?

Drawing is but a small part of the engineer's work. More or less calculating has to be done; many hours must be spent in figuring strains, estimating weights, determining speeds and what not. This brings us to the test of convenience in calculation, to the stronghold of the metric advocates. It is just here that Dr. Edward Wigglesworth in his metric tracts comes out the strongest in his peculiar style. He says that Americans, self-ruling, are really too lazy, while merely claiming to be too stupid, to use the system. He says, "Shame on a country which to party gives up what was meant for mankind." It is claimed that the decimal notation of the metric rule gives great facility in calculating, but that this is not its sole advantage.

Mr. Frazer says: "Let the carpenter or mason be asked how many tons of water a structure, whose *external* (I guess he means *internal*) dimensions are given, by his rule, will contain, and they will acknowledge that the decimal division is not the only advantage of the metric system, but that another is the perfect relation of extension, capacity and weight." For a structure 5 feet square and 10 feet deep the carpenter would divide, in his head, 250 by 32 and say 8 tons, nearly, or 7·8125 tons exact of the tons of 2000 pounds in use, in all such measurements. The metric system would give, for a nearly similar

structure, say $1{\cdot}5 \times 1{\cdot}5 \times 3$ metres, a result obtained by multiplying only; but what then? This problem applies to water only. If these spaces were to be loaded with bricks the metric multiplication must be still further multiplied by the specific gravity of bricks, thus: $1{\cdot}5 \times 1{\cdot}5 \times 3 \times 1870 = 12{,}622{\cdot}5$ kilos, while our mason's sum would read $5 \times 5 \times 10 \times 125 = 31{,}250$ pounds of common hard bricks, with an ease of calculation rather in favor of the two-foot rule.

I have mentioned the innumerable books which have been prepared, simplifying processes of calculations by tabulating the results of experiments on a basis of the inch unit. Of these books the English experiments form a large bulk of the valuable engineering knowledge of the world. Hodgkinson, for example, experimented with the crushing resistances of various substances, and the result of his experiments are in the possession of all engineers. He took samples in cylindrical form, 1 inch diameter, 2 inches long each, for these experiments. Armengaud quotes these experiments and tabulates the results, saying they were obtained by Hodgkinson, *avec des cylindres de* $0^{m}0254$ *de d*^{tre} *sur* $0{\cdot}508$ m. *de haut*^{r} $= 1'' \times 2''$, and from these he deduces, for example, that *ash* has a crushing resistance of from 610 to 653 kilos per square centimetre.

Mr. Trautwine, quoting Eaton Hodgkinson's experiments, also tells us that ash, weighing from 45 to 53 pounds per cubic foot, has a crushing value of 8600 pounds per square inch. Now, 1 pound per square inch $= {\cdot}0703077$ kilo per square cm., or 1 kilo per square cm. $= 14{\cdot}2232$ pounds per square inch, $\frac{8600 \text{ pounds}}{14{\cdot}22} =$ about 605 kilos to the square cm. Here, from Trautwine's deduction, the metric using engineer will employ 605 as a factor where we use 8600 in the same case. He, because his unit of measurement is less, or, rather requires more figures to express it, multiplies these many figures by a lesser factor, while we, expressing our dimensions with lesser figures, use with these figures a larger factor. In other words, we can complete our calculation sooner because we are able to deal with the largest measures compatible with convenience. We can use the cubic inch, the cubic foot or the cubic yard, at our pleasure, just as the mechanic selects his tools in accordance with the extent of his work, and don't fool time away driving at a rail-road spike with a tack hammer.

I have before me, as I write, French books and German books on

mechanical engineering. In some, both French and German, all or nearly all, formulas for strains are expressed in kilos per square cm., while Prof. Reuleaux, in his many valuable books of reference, seems to adhere to kilos per square millimetre. Now, to test the matter of convenience, in a way familiar to all mechanical engineers, let us go to Reuleaux for our information as to the strength of cast iron, in the familiar equation for beams of $W = \frac{4\ s\ b\ h^2}{l}$. Reuleaux says the value of s may be taken as 4 kilos per square mm.; this equals 400 kilos per square cm., or 5689 pounds per square inch. Let our example be a cast iron beam of rectangular section, 9 inches deep, 4 inches wide, and 10 feet between its supports; given, to find its safe load in the middle. Let us round up these dimensions into a somewhat similar beam, measured in mm., $230 \times 100 \times 3000$. Now, $h = 230$ or 9, $b = 100$ or 4, $L = 3000$ or 120.

The formula then reads

$$\frac{4 \times 4^k \times 100 \times 230 \times 230}{6 \times 3000} = 4702^k \text{ for all dimensions, in mm.}$$

or

$$\frac{4 \times 400^k \times 10 \times 23 \times 23}{6 \times 300} \text{ for all dimensions, in cm.}$$

If we take 6 from the denominator, then

$$\frac{4 \times 66{\cdot}6 \times 10 \times 23 \times 23}{300}$$

If we make the formula good for cast iron only, and use centimetres in the numerator and metres in the denominator, which is the best we can do, $\frac{2{\cdot}664\ b\ h^2}{l}$ for cast iron $= \frac{2{\cdot}664 \times 10 \times 23 \times 23}{3}$.

Compare this with $\frac{4 \times 5689 \times b\ h^2}{6\ l}$ which reduces to $\frac{316\ b\ h^2}{l}$ for cast iron, and reads $\frac{316 \times 4 \times 9 \times 9}{10}$.

My note-books are full of such examples as this; it has been my wish to test this matter thoroughly; my experience covers many examples of engineers and draughtsmen educated in metric-using countries, who, when they come to us learn to use our measures as quickly as we can learn to use theirs, but adopt our methods of calculation as involving fewer figures. Thus, for all practical purposes, in strains, what

will be strong enough in kilos, if we assume two pounds to the kilo, will be near enough right, and if the "grand truth of mechanics is that properties or dimensions of parts of machinery to accomplish any given purpose will be unaffected by any standard of length or weight applied to the part," it is therefore possible to arrive at the theoretical proportion by either system, and it is presumable that the workman will select the easiest one to work with, the more so if the easiest one happens to be the one he has been most used to. I have yet to see the example of a metric-educated draughtsman working in millimetre calculations on an inch-measured machine, while with our own experience with both we could follow him in either.

Cubic inches go farther than cubic millimetres, *i. e.*, they involve fewer figures in their expression; because a cubic inch is 16000 larger than a cubic millimetre, it is 16 times larger than a cubic cm.; and while, again, the litre is may be 64 times larger than the cubic inch, yet is the cubic foot 27 times larger than the litre, and between the litre and the cubic metre there is no unit of measurement; 10 litres, like our gallon, has an edge only expressable in decimals.

The harmonious relation of extension, bulk, weight and all that comes out strongest when we deal with distilled water. Away from that precious fluid, and we are required to know and use the weights of matter as they relate to water. I must confess I see no difference in favor of hunting up in books the specific gravity of matter, or in looking for the weight of matter in pounds per cubic inch, or foot, or yard.

With distilled water engineers have little to do; when they note the solid matter accumulating in their boilers, they wish they had more to do with it. In hydraulic calculations the weight of distilled water, however, may be near enough to the weight of the water they have to deal with to enable them to reap all the advantages desirable from the system, did not the small units, the millimetres, or the many figures in the decimals of the metre, mar the result in a labor-saving point of view.

The value of the drawing room system is tested or tried when the drawings reach the machine shop. It is there that errors are found out. An incorrectly figured drawing costs nothing on account of the errors so long as that drawing rests quietly in its drawer; but it costs fearfully when the error is discovered in the partially finished machine. All engineers agree on one thing, viz., the fewest possible figures that

can be used to express dimensions clearly, the easier it is to work to the drawing, and the less liability to make mistakes. Beautiful as is a decimal system in calculation, and we all use it, save in mental arithmetic, it has been found advisable to avoid the use of decimals as far as possible on the drawings used in our work-shops, even in metric using countries. A misplaced point is an easy error to make, and may cause no end of trouble and expense.

I had hoped for gain in the drawing room from the use of metric scales; I expected to find more than in the machine shop; I have been disappointed in both.

In the machine shop we come to test the value of shop sizes and merchant sizes, or rather the series possible in both, with one or the other system. For what is in use abroad, we look to Germany rather than to France for information useful to us, inasmuch as in Germany the metric system was taken up at a late day, and was introduced in its entirety without shock. To united Germany anything was better than their frightful confusion of 15 inches in use, all differing from the inch still used with their screw threads, and differing from the inch of England. The metric system is incomparably better than their before entire want of any uniformity. With us the matter is very different, as will be seen more clearly as we advance. We divide our unit, in practice, into just what parts are best suited to express our practical wants, and the system in our machine shops is uniform over a continent.

The first item of manufactured matter entering the machine shop door is bar iron. The merchant sizes of round, square, etc., in America, are by $\frac{1}{16}$, by $\frac{1}{8}$, by $\frac{1}{4}$, etc. In Germany, similar bars advance in size by 1 mm. up to 40, by 2 mm. from 40 up to 80, and by 5 mm. above 80. This system is memorizable by 40 and 80—by 1, 2 and 5. It is the best that can be done with a system tied up to an unhalvable scale. It does not agree with the English or American merchant sizes except in a few sizes. The system of bolts, diameters and threads per inch common or general over the continent of Europe is that known as the Whitworth system. They still adhere to this system as they do to the English system of gas and steam pipes and their fittings. The Whitworth system pitches its threads to even numbers or half numbers per inch in length. These pitches are easily obtained from the lead screws of all lathes, which are 2, 4 or 6 threads per inch as a rule. Having given up the inch, the Germans formulate their threads

per diameter (see tables at the end of this paper). For the names of the bolts, they must either retain their English names, and call a 25·4 mm. bolt one inch, or they must call it what it is, 25·4 mm., but some call it 25 mm., and make it ·4 mm. larger. This inch bolt has 8 threads per inch, and, as the diameter, too, is 1 inch, it can be said to have 8 threads per diameter. A $1\frac{1}{8}$-inch bolt measures 28·6 mm.; it may be called 29 mm. size; it must be cut out of 29 mm. iron, the nearest merchant size, with a loss of $\frac{4}{10}$ of a millimetre. This loss don't seem much, but the dies which have to cut it off tell the story very soon. The Whitworth scale gives the same pitch to $1\frac{1}{8}$ and $1\frac{1}{4}$ screws, viz., 7 per inch. The exclusive metric shops call the one $7\frac{1}{8}$ threads per diameter, and the other $8\frac{3}{4}$, and yet they are practically the same and must be cut with the same combination of change wheels on the lathe. Here is a precious example of what comes from trying to harmonize two systems under one nomenclature. The screw system in general use is so good, it has been so long in use, its disturbance would shock so many interests, that it is unwise to give it up, as unwise as it would be to adopt the American gas pipe system in place of the English, or for us, for sake of uniformity with England and Germany, we should attempt to force the adoption of their system into our houses.

Imagine the hue and cry if some "benevolent despot," for the good of mankind in general and Europeans in particular, should direct us to change our "fittings" to English standards, none of which would fit the pipes we have in our houses. Why, we are even vexed enough if we are sold a "sleeve" which will not fit a pipe put in place thirty years ago.

America has, for the last half century, been striving in its own way, towards equalization of its standard sizes. The immense railroad industries demand this. Standard wheels on standard axles—standard fit sizes for both—are all founded on an inch scale of sizes.

Standard shafting for mill gearing gives a good example. It has been demonstrated that bars carefully rolled to size in rounds can be reduced to turned shafting with the loss of $1\frac{1}{2}$ mm., or $\frac{1}{16}$ inch to the diameter. Hence, bars 2, $2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{3}{4}$, 3 inches, etc., are made into shafts $\frac{1}{16}$ less in diameter, sold by their full size names, *i. e.*, by the name of the iron from which they have been made and designated by the affix "shafting size." A 2-inch shafting size bar measures $1\frac{15}{16}$ inch, and a pulley ordered to-day with an eye to fit a $2\frac{1}{2}$ or a 4-inch shaft made

thirty years ago will be found to be to size. Now this American shafting sells freely in Europe and no one complains of its size. He can command the markets of the world who can make the best machinery at the least cost, and that machinery will be taken and used and no questions asked about its inches or its millimetres.

A scale of shafting sizes so uniform and so easily expressed by $\frac{1}{4}$ up to $3\frac{1}{2}$ and by $\frac{1}{2}$ inches to sizes above 3, is met in metric countries by the ease of an advance by 5 mm. only. To obtain the economy of American shops their shafting sizes should be $1\frac{1}{2}$ mm. less than their name, *i. e.*, a 100 mm. shaft should be made $98\frac{1}{2}$ mm. diameter, but the Germans have seen fit to retain even sizes and thus are obliged to use 57 mm. iron to make a 55 mm. shaft, and 93 mm. iron to make a 90 mm. shaft, while on still larger shafts they must be content to lose 5 mm. at each turning. Such is the usage now, so far as we can learn.

The shop sizes in America harmonize with the merchant sizes and with convenience. We cannot change them. It would be unwise, I think, to do so in face of the obtainable metric sizes if we could. One other example of good and bad systems, and I have done with this part of our subject.

An essential of all machine shops is a drill system; a series advancing by $\frac{1}{16}$ up to 1 inch, and by $\frac{1}{8}$ inch up to 2 inches, is equivalent to an advance by $1\frac{1}{2}$ mm. in a metric series. Such an advance as $1\frac{1}{2}$ mm. is impracticable, because it must be memorized entire; it affords no holding place for the memory. Twist drills were first made in America; they were so good, so useful, that American drills came to be the rage in Europe. After a time good makers there began their manufacture. I will mention one house, founded in 1834, that of Heilmann, Ducommun & Steinlen, at Mulhouse (Alsace), one of the best known houses in all Europe. They make twist drills from 10 mm. up to 50 mm., advancing by 1 mm., but their price list tells us that the sizes marked in bold face type are the sizes in use in their own shop. These sizes are: 10, 12, 15, 18, 20, 23, 25, 28, 30, 32, 35, 37, 40, 42, 45, 47, 50. Here a series of sizes approximating the English ones is adopted, but it is a series which must be memorized entire, as its advance is not by two or by three either, in regular sequence. We cannot question the wisdom of the men who have selected these shop sizes to meet their known wants; they rank too high as workmen, they know too much to challenge criticism. Doubtless, this scale of

sizes is about the best they can do with the metric system; we would not tie ourselves to it. I could continue the list of practical difficulties until I had filled a volume. They run through the entire list of all that goes to make up the requirements of our profession, and show how unwise we would be to change, if we could do so for the sake of harmony with Europe. We have not adopted the Whitworth system of screws in America, and yet, by so doing, we would place ourselves in harmony with all Europe. We recognize objections to the system, and when those objections were clearly pointed out by Mr. William Sellers and he proposed a system free from the objections, his system was accepte l by the committee of the Franklin Institute and then by many departments of our government. Had the metric system shown itself to be the perfect system it is claimed to be, it too, would have been taken up more generally at a time when it was easier to have done so than now.

The American mind is quick to note what is to the advantage of American mechanics. We take up quickly what is good to hold to, and we will not accept what we have demonstrated to be less useful. This was made manifest to Prof. Reuleaux, Director of the Industrial Academy, Berlin, and is expressed by him in his report on motors and machines at Paris Exposition, 1867. In commenting on the many novelties from America he says, "Upon the whole it may be said that in machine industry England has partly lost her formerly undisputed leadership, or that she is about to lose it. The healthy young transatlantic industry, which continually withdraws from us energetic and intelligent heads and robust hands, makes, with the aid of her peculiar genius, the most sweeping progress, so that we shall soon have to turn our front from England westward." Then, in commenting on the rapidity with which American ideas were finding a home in Germany, speaks of the genius for inventions of this kind as peculiar to us—"They are distinguished from us by more direct and rapid conception. The American aims straightway for the needed construction, using means that appear to him the simplest and most effective, whether new or old." * * * "The American really constructs in accordance with the severest theoretical abstractions, observing on the one side a distinctly marked out aim, weighing on the other the available means or creating new ones, and then proceeding regardless of precedents, as straight as possible for the object." * * * "This spirit is strikingly

prominent in the (Wm. Sellers') system of screw threads which he has boldly placed alongside of the old venerated Whitworth system, in spite of the terror of its numerous adherents, after he had discovered actual deficiencies. A proper valuation of this proceeding contains the most instructive hints for our higher technical institutions."

There is an irreconcilable discord between the inch and the divisions of the metre. The inch has become fixed to a greater extent in dollars and cents, in fitness and convenience, in this country than in Germany, and yet there, in some cases I have shown, it cannot be given up. To keep our scale of sizes and use French dimension sizes would "furnish a precious example of the simplicity of the decimal system." I was a signer of the majority report of the Franklin Institute which opposed the compulsory adoption of the metric system. That report was prepared and written by the chairman, Mr. Wm. P. Tatham, since made President of the body which adopted it, as their view of the matter. Mr. Tatham is a man of culture and a hard student. His business as maker of lead pipes would have been less affected than that of almost any other manufacturer by the introduction of the metric system. He said, and I subscribed to the statement, that he believed that the ultimate benefits of the change proposed would be of less value than the damages during the transition. This was on the suppositious view that ultimately some would be benefitted. As an engineer I can see no possible good to come to American machinists from the change. Its introduction exclusively would not diminish his labor in any way; it would not cheapen his product, it would increase its cost. It is in fact, however, so impossible in view of existing matters and existing harmony in interchangeable matter, that should the metric standard be made the only legal standard in America to be used in buying and selling, the engineering establishments now in existence could not heed the law, but must perforce use their existing tools and gauges of precision, and continue to make material in conformity with existing matter.

The metric system was admitted here to an equal fostering in point of law in 1866. It had not been legalized in any way when we, for good reasons, introduced it into our own workshop in Philadelphia, and yet, at that time, we asked no one's permission to do what we pleased in the metrological management of our own business. We had a chance to try the system in making something which did not clash

with existing merchant sizes; once having perfected an organization in this department we became fixed in its continuance. Precisely the same reasons why we cannot change our general system into the metric hold against our giving up the metric system in the departments where it is in use.

If the change to the metric system will aid commerce, let the merchants do as we have done—try it. Commerce depends, in a large measure, on the possible out-put of our workshops. The engineer controlling the workshop and who, to be successful, must be a merchant too, knows too well how he stands to give up a practically useful system more convenient to him after having tried both, for the sake of any fancied conformity with other countries. He can give up no vantage ground. His success in his life-battle in these days of active competition depends upon wise economies to enable him to prosper. He has no more reason to cripple himself with an inconvenient system of metrology than he has to give up a tariff of protection on his production in order to make it easier for the world to compete with him.

I am tempted to touch on the educational view of the subject, but will content myself with very few words. When engineers are told that the change to the metric system would save two years, or one year, in the school life of every child, they ask how many years are now devoted to mathematics only, in the average four years' schooling of the mass of our boys, and ask, what is to be lopped off to make this saving? Many a good workmen who has risen to a high rank among educated mechanical engineers had too few years at school to admit of a month's saving in any one branch of his studies.

It is the thing just now to favor the change. A young engineer enlisting himself in the ranks of the metrical reformers (?) buys a cheap scientific notoriety. He is brought into sympathy with the self-constituted advanced thinkers. Those who oppose the change, after having become familiar with both, are said to "sever themselves from the congenial sympathy of the enlightened public opinion of to-day." The mechanical engineer can accept nothing as true until he has demonstrated the truth by experiment; at least, in anything capable of being put to the test of experiment. It is in the power of any intelligent man to test the metric system as others have done. He will, I think, find that the *savants* who originated the scheme before me-

chanical engineering, as it now exists, was known as a profession, made the mistake of beginning at the wrong end, the big end of the scale, the size of the world, and by the time they had cut it up or down to human wants it came out less fitted to human requirements than if they had recognized in the beginning the needs of the beings who were to use it.

Our metrological reformers urge us to adopt a new system in place of our present one, a system that harmonizes in no way with anything we now use. This new system is practically based on a certain measure over 39 inches long. This is cut up into 1000 parts, and 100 of these parts cubed gives their primary vessel of measurement. The contents of this vessel in distilled water under certain conditions is their pound weight. Had the English yard of 36 inches been so treated it would have been as good a system, but no better. It would have been as inapplicable comfortably to our profession as is the metric. The wonderful extension of the metric system to time and infinite space was given up as impracticable long ago, and we are now asked to bear the shock of a mighty change to use this *inconvenient* system, this unhandy system of ten, for the sake of uniformity with some other peoples' of the world.

In conclusion, when we take into consideration the enormous interests involved in manufacturing in America; if it is, as we think, unwise to tamper with the existing metrology of our workshops, the question may well be raised as to the wisdom of enforcing the metric system in trade generally. The practical mind of Americans has already dispensed with much useless stuff, coming to us with our old metrology; is it not better to continue to amend what we have, to encourage the uniformity so desirable, rather than to attempt to make all things new; but in no respect practically better, at so frightful a cost?

WHITWORTH'S SCREWS.

In use in Europe, especially in Germany.

Diameter.—English Inch.	Diameter.—Prussian Inch.	Diameter. Millimetre.	Diameter at root of thread. English Inch.	No. of threads per Diameter.	No. of threads per Inch—English.	Diameter.—English inch.	Diameter.—Prussian inch.	Diameter.—Millimetres.	Diameter at root of thread, English Inch.	No. of threads per Diameter.	No. of threads per Inch—English.
$\frac{1}{4}$	0·243	6·4	0·186	5	20	$2\frac{1}{4}$	2·185	57·1	1·930	9	4
$\frac{5}{16}$	0·303	7·9	0·241	$5\frac{5}{8}$	18	$2\frac{1}{2}$	2·428	63·5	2·180	10	4
$\frac{3}{8}$	0·364	9·5	0·295	6	16	$2\frac{3}{4}$	2·671	69·8	2·384	$9\frac{5}{8}$	$3\frac{1}{2}$
$\frac{7}{16}$	0·425	11·1	0·346	$6\frac{1}{8}$	14	3	2·913	76·2	2·634	$10\frac{1}{2}$	$3\frac{1}{2}$
$\frac{1}{2}$	0·486	12·7	0·393	6	12	$3\frac{1}{4}$	3·156	82·5	2·857	$10\frac{9}{16}$	$3\frac{1}{4}$
$\frac{5}{8}$	0·607	15·9	0·509	$6\frac{7}{8}$	11	$3\frac{1}{2}$	3·399	88·9	3·107	$11\frac{3}{8}$	$3\frac{1}{4}$
$\frac{3}{4}$	0·728	19·0	0·622	$7\frac{1}{2}$	10	$3\frac{3}{4}$	3·642	95·2	3·323	$11\frac{1}{4}$	3
$\frac{7}{8}$	0·850	22·2	0·733	$7\frac{7}{8}$	9	4	3·885	101·6	3·573	12	3
1	0·971	25·4	0·840	8	8	$4\frac{1}{4}$	4·127	107·9	3·805	$12\frac{7}{8}\frac{7}{2}$	$2\frac{7}{8}$
$1\frac{1}{8}$	1·092	28·6	0·942	$7\frac{7}{8}$	7	$4\frac{1}{2}$	4·370	114·3	4·055	$12\frac{15}{16}$	$2\frac{7}{8}$
$1\frac{1}{4}$	1·214	31·7	1·067	$8\frac{3}{4}$	7	$4\frac{3}{4}$	4·613	120·6	4·285	$13\frac{1}{16}$	$2\frac{3}{4}$
$1\frac{3}{8}$	1·335	34·9	1·162	$8\frac{1}{4}$	6	5	4·856	127·0	4·535	$13\frac{3}{4}$	$2\frac{3}{4}$
$1\frac{1}{2}$	1·457	38·1	1·287	9	6	$5\frac{1}{4}$	5·098	133·3	4·790	$13\frac{2}{3}\frac{5}{2}$	$2\frac{5}{8}$
$1\frac{5}{8}$	1·578	41·3	1·369	$8\frac{1}{8}$	5	$5\frac{1}{2}$	5·341	139·7	5·020	$14\frac{7}{16}$	$2\frac{5}{8}$
$1\frac{3}{4}$	1·700	44·4	1·494	$8\frac{3}{4}$	5	$5\frac{3}{4}$	5·584	146·0	5·238	$14\frac{3}{8}$	$2\frac{1}{2}$
$1\frac{7}{8}$	1·821	47·6	1·591	$8\frac{7}{16}$	$4\frac{1}{2}$	6	5·827	152·4	5·488	15	$2\frac{1}{2}$
2	1·942	50·8	1·716	9	$4\frac{1}{2}$						

TABLE OF SCREWS.—By REULEAUX.

Diameter of Screw d — mm	Diameter at root of Thread d_1 — mm	Threads per 25 mm	Pitch p — mm	WHITWORTH'S Diameter d — Inches	Threads per Inch	Pitch in Eighths of an Inch
6	4·1	7	7	¼	20	5
8	5·9	6	8	⅜	18	5⅓
10	7·7	5½	10	½	16	5
12	9·5	5	11	⅝	12	6
15	12·2	4½	13	¾	11	6½
18	14·9	4	15	⅞	10	7½
21	17·6	3½	17	1	9	7⅞
24	20·3	3	20	1	8	8
27	23·0	3	22	1¼	7	7⅛
30	25·7	2½	24	1¼	7	8⅛
34	29·3	2½	27	1½	6	8⅓
38	32·9	2½	29	1½	6	9
42	36·5	2¼	32	1⅝	5	8⅛
46	40·1	2¼	35	1¾	5	8¾
50	43·1	1⅞	38	1¾	4½	8⅞
55	48·2	1¾	41	2	4½	9
60	52·7	1½	45	2¼	4	9
65	57·2	1½	48	2¼	4	15
70	61·7	1½	52	2½	4½	9½
75	66·2	1⅜	55	2½	4	10

TABLE OF AMERICAN AND ENGLISH GAS PIPES.

Nominal Diameter.	U. S. Standard. Act'l outs. Diam. in Engl. in.	U. S. Standard. No. of Threads per inch.	English Standard. Act'l outs. Diam. in Engl. in.	English Standard. Act'l outs. Diam. in mm.	English Standard. No. of Threads per inch.	Nominal Diameter.	U. S. Standard. Act'l outs. Diam. in Engl. in.	U. S. Standard. No. of Threads per inch.	English Standard. Act'l outs. Diam. in Engl. in.	English Standard. Act'l outs. Diam. in mm.	English Standard. No. of Threads per inch.
$\frac{1}{8}$	0·405	27	0·406	10·318	19	$2\frac{1}{4}$	.....	.....	2·625	66·674	11
$\frac{1}{4}$	0·54	18	0·531	13·493	19	$2\frac{1}{2}$	2·875	8	3·0	76·199	11
$\frac{3}{8}$	0·675	18	0·625	15·875	19	$2\frac{3}{4}$	....., ...		3·125	79·374	11
$\frac{1}{2}$	0·84	14	0·812	20·637	14	3	3·5	8	3·5	88·898	11
$\frac{5}{8}$	.....	.....	0·906	23·018	14	$3\frac{1}{2}$	4·0	8	3·937	100·01	11
$\frac{3}{4}$	1·05	14	1·031	26·194	14	4	4·5	8	4·437	112·71	11
$\frac{7}{8}$	.....	.....	1·187	30·162	11	$4\frac{1}{2}$	5·0	8	.....	.....	.....
1	1·315	$11\frac{1}{2}$	1·312	33·337	11	5	5·563	8	.....	.....	.....
$1\frac{1}{4}$	1·66	$11\frac{1}{2}$	1·625	41·274	11	6	6·625	8	.....	.....	.....
$1\frac{1}{2}$	1·9	$11\frac{1}{2}$	1·875	47·624	11	7	7·625	8	.....	.....	.....
$1\frac{3}{4}$	.....	... ...	2·125	53·974	11	8	8·625	8	.....	.....	.....
2	2·375	$11\frac{1}{2}$	2·375	60·325	11	9	9·688	8	.....	.....	.....
						10	10·75	8	.....	.....	.....

THE WEAKENING OF STEAM BOILERS BY CUTTING HOLES IN THE SHELL FOR DOMES AND NECKS.

By W. Barnet Le Van.

The weakening effect of cutting large holes in boiler shells for receiving steam domes or drums is well known among boiler makers, and in order to preserve as much as possible of the original strength of the shell they cut a hole much smaller than the diameter of the steam dome, with the idea that the shell is weakened only in proportion to the size of the hole cut, which is a great error. The weakening effect is proportioned to the section of the dome joining the shell, independent of the size of the hole cut.

The effect of an equal pressure upon both sides of that part of the shell covered by the dome is to deprive it of its direct acting tensile strength, in resisting an enlargement of the circle of the boiler, and substitute in its stead that resistance made by a curved plate pulled in the direction of its chord.

The plate of the shell at the base of the steam dome has the steam pressure on each side of it, and there is nothing to retain it in its arched shape; in other words, it is nothing more than a bent stay which the pressure of the steam tends to pull into a straight line.

As this is but an inconsiderable fraction of the tensile strength, the boiler is weakened in proportion. To make this good the boiler should be stayed, to compensate for the section of plate represented by the diameter of the dome. But better still is to have *no dome at all.*

It sometimes happens that from commercial considerations a dome is insisted on, and in the resultant conflict with the judgment and experience of the engineer, as is too often the case in making a plan for boilers, the latter has to submit. A steam dome is just such a case in point.

If domes are used at all, great attention must be given to the construction of them. They should be contracted at the lower part, and connected to the shell of the boiler by a neck of moderate diameter, and of such strength as to thoroughly make up for the cutting away of the shell of the boiler. I doubt the utility of steam domes under any circumstances, as they only act as a partial condenser of the steam passed into them.

Mr. Wilson says, without considering the cooling effect on the steam by the circumference of a large dome, exposed to the atmosphere, this would be a correct conclusion if the steam flowed slowly and quietly into the dome. But this is not the case with the engine at work, when the steam rushes into and through the dome with great velocity, and is liable to take a quantity of water along with it, causing the steam in the dome to be actually wetter instead of drier than the steam in the rest of the upper portion of the boiler.

Zerah Colburn says, "steam domes, if necessary, are necessary evils. They weaken the boiler materially wherever they are applied, also are very expensive. There are many locomotive boilers which have done and are doing well without domes, and with perforated steam pipes, taking steam along the whole length of the upper part of the boiler."

It is a well-established fact that a locomotive boiler gives off the greatest amount of power per square foot of heating surface. Now if locomotive boilers do as well without a dome, there is no valid reason why stationary boilers should not do well without them if properly proportionated.

Steam domes afford additional steam room, which may be desirable; but a simple calculation will show that by increasing the diameter of a 48-inch diameter boiler, 12 feet long, to 51 inches diameter, as much additional capacity will be obtained as is contained in two steam domes of the ordinary size (30″ x 24″), and the larger sized boiler, without the steam dome, will resist more steam pressure per square inch than the smaller boiler with the steam dome attached. By slightly increasing the diameter of the boiler it is hardly weakened, and the extra iron required will be but one-fifth that used in making the steam dome, saying nothing of workmanship, etc.

It is a well-known fact that steam domes, by exposing additional cooling surface, occasion a considerable loss of heat. This, although a minor objection when compared with others, is an additional reason why every effort should be made to substitute perforated pipes or some equivalent arrangement.

The Corliss Steam Engine Company, of Providence, R. I., do not use steam domes on any of the boilers supplied by them in their extensive business, and it is well known to every one what success they have had in the economical making as well as using of steam.

The New York and Erie Railway have a number of locomotives

without domes, and they carry their water as well as any locomotive boilers on the road.

Locomotives built by Corliss & Nightingale for the Cleveland and Pittsburgh Railroad, and having no domes, were reported to work as well as locomotives having steam domes.

In England and on the continent a large number of locomotives have been in use for a long time without domes. Notable may be mentioned the Great Northern Railway, from designs of Patrick Stirling, Locomotive Superintendent; South Eastern and the London, Brighton and South Coast Railways. On the latter road, from the designs of Mr. William Stroudley, Superintendent, in his boilers the longitudinal seams are all double-riveted, with butt strips inside and out, the latter being countersunk, to enable the rivets to fill the holes well up. The corners of the fire-box and also the fire-box casing are of large radius, that of the former being three inches, and that of the latter six inches. All the rivet holes in the boiler are drilled and all the edges of the plates planed. The man-hole ring is of sufficient cross-section to bring up the strength of the boiler at the man hole to equal that of the strongest seam. (*Engineering*, vol. 13, p. 91, 100.)

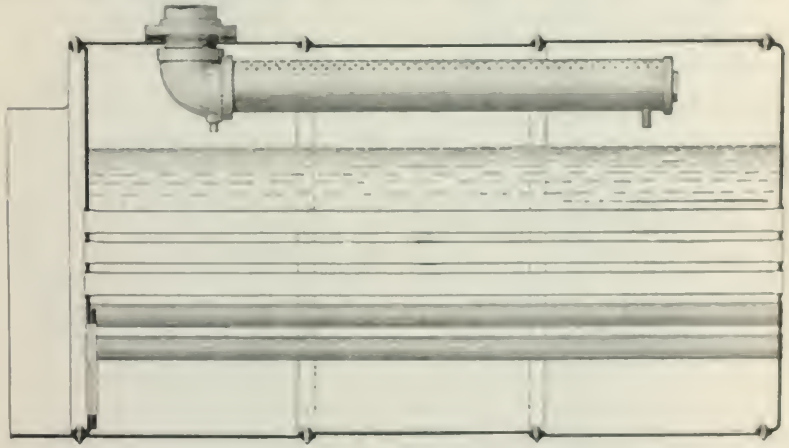


Fig. 1

The Swiss North Eastern and the North Eastern Railway, of Switzerland, have no domes since 1872.

Russian locomotives, built by Messrs. Schneider & Co., Creusot, France; Messrs. Kraus & Co., Munich; Glasgow and South Western Railway, James Sterling, Superintendent.

A substitute for a dome is a pipe placed inside of the boiler near the top of the steam space, the upper part of the pipe being perforated with small holes. The smallest holes should be made where the ebullition is greatest, which is over the fire-grate. It would require 250 holes of $\frac{1}{4}$ inch diameter, or 1000 holes $\frac{1}{8}$ inch in diameter, to give the area of a circular opening of 4 inches diameter.

Large steam pipes, containing more than one cylinder full of steam, tend to equalize the delivery of steam from the boiler, and thus to prevent priming. As there is no pressure on such pipes, they may as well be 6 or 8 inches in diameter as to be smaller.

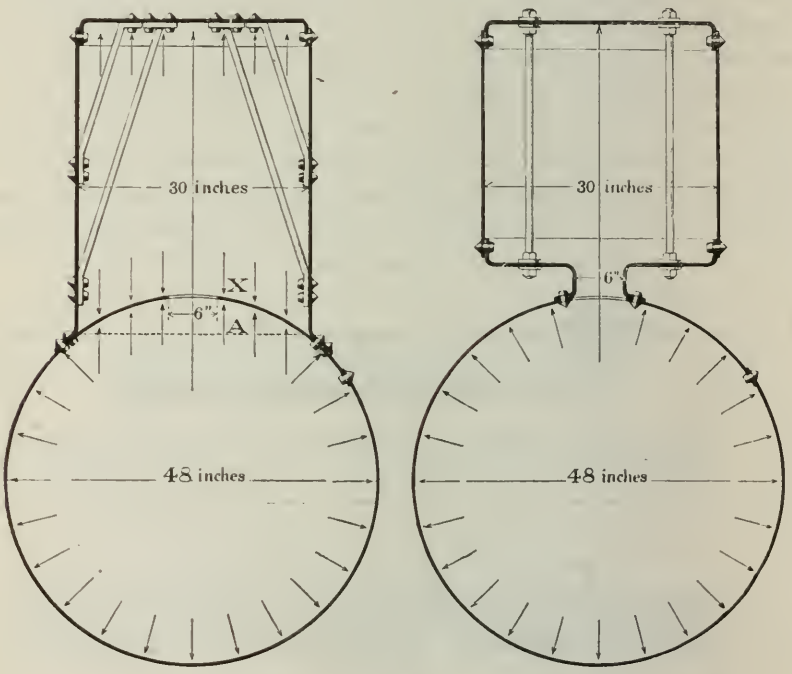


Fig. 2.

It is not generally known, but nevertheless is a fact, that a large number of boilers sent out are under internal strains, resulting from bad workmanship, which, no doubt, in some cases will equal the proproposed working pressure. These strains reduce the ultimate strength of the boilers independent of their being further weakened by cutting large holes for domes or necks.

The pressure in a cylinder boiler practically radiates from the axis

of the cylinder to the circumference, tending to preserve the circular form, and thus keep the plates of the shell in equal tension.

Now, when a steam dome is used with a small hole cut in the shell this effect is destroyed, from the fact that the instant the pressures inside and outside that portion of the shell plate covered by the dome are equal it becomes merely a bent stay, and affords but little strength to resist the bursting pressure on the shell of the boiler, having a tendency to become straight, as shown by the dotted lines at *A* (Fig. 2), and having no support from internal pressure to assist it in keeping a cylindrical shape, the pressure under and over the shell being the same as shown in the cut at *N*, causing the shell of the steam dome to be thoroughly strained and brought to a bearing, thereby stretching the boiler shell plates to the extent of their greatest elastic limit, and reducing its strength to a minimum.

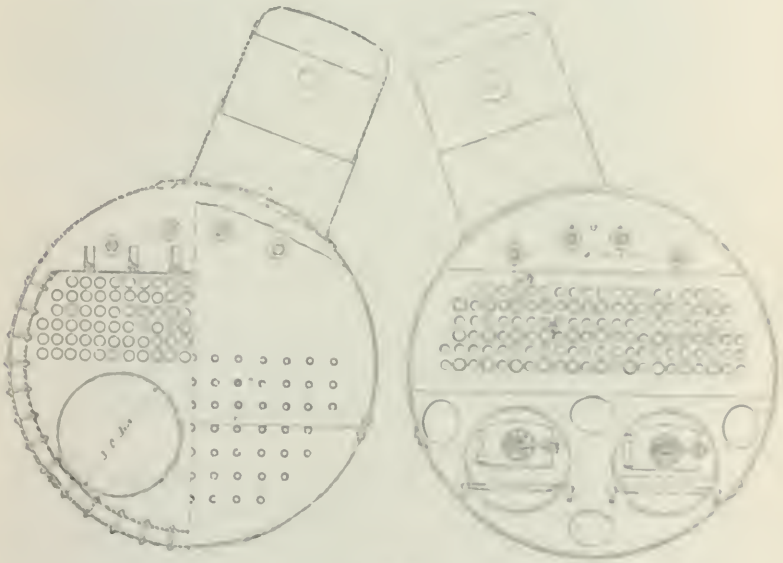


Fig. 3.

That steam domes are the cause of the weakening of boiler shells we have ample evidence. In England, on June 26th and July 1st, 1875, disastrous boiler explosions took place on board the screw steamers *Mareasite* and *Renown*. "The boiler that exploded the one on the port side, and it gave way at the base of the cylindrical steam dome, which was attached to the boiler shell by a double row of

rivets, the plate of the dome being flanged, and the shell of the boiler beneath the dome left intact, with the exception of a man-hole cut in it." Fig. 3 represents the boilers of the *Marcasite*. The boilers in the two vessels were of similar construction, save that in the case of the *Renown* the steam dome was farther from the front plate, and was thus out of the uptake.

It is impossible to examine the cut without being at once struck with the weakness induced by the mode of attaching the steam dome —a weakness which is so justly remonstrated against in both reports on the explosion, as contributing so strongly to the disasters of these boilers.

The editor of *Engineering* says, editorially: "Yet the boilers were were made by firms of high standing—those of the *Marcasite* by Messrs. D. Adamson & Co., of Hyde Junction, and those of the *Renown* by Messrs. W. B. Thompson & Co., of Dundee—and hence it can scarcely be wrong to conclude that even amongst experienced boiler makers, turning out what are in other respects carefully designed boilers, the weakening effect of large steam domes has not been estimated at its full value."

The official assessors say in their report upon the explosion on board the *Renown* (three persons being killed):

"The shell plate at the base of a steam dome, having the steam pressure on each side of it, has nothing to retain it in its arched shape."

That is to say, it is nothing more than a bent stay, which the pressure of the steam tends to pull into a straight line. The plates of the shell were flattened down more than an inch from their original form, as shown by the dotted lines in Fig. 4.

"In both these explosions, the junction between the dome and shell was clearly the weakest place in the boiler, and in the *Renown* this point was so weak as to fail at the pressure to which the safety valves were loaded. Both disasters point strongly to the necessity of paying greater attention to the construction of domes, and to the desirability—if large domes are used at all—of contracting them at the lower part, and uniting them to the shell by a neck of moderate diameter, and of such stiffness as to thoroughly make up for the cutting away of the shell plate." In some cases, boilers fitted with large domes have been strengthened by straight stays placed across the opening from side to side and riveted to the shell. It is, however, almost impossible to so

apply these stays as to thoroughly compensate for the weakness caused by the application of the dome, while they give rise to a cross bending action at the points where they join the shell plates, which may, under some circumstances, lead to bad results.

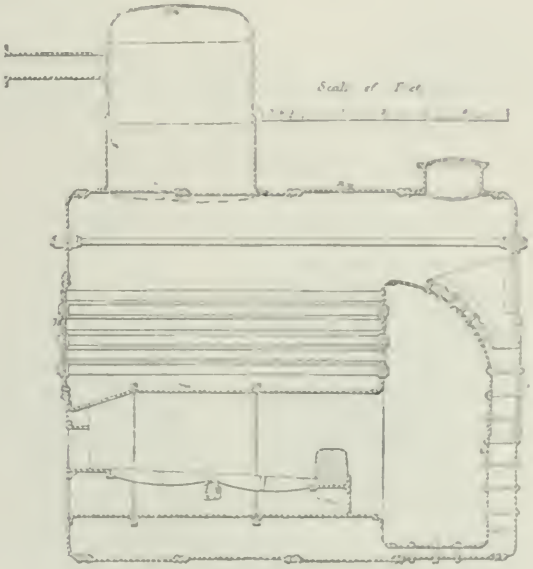


Fig. 4.

In the case of the *Marcasite* (three also killed), the Court remarked that it was imperative that the construction of boilers, especially that part called the *steam dome* (when such is used), should be most carefully considered and carried out, both as regards workmanship and material.

In November, 1851, a Committee on Science and the Arts of Franklin Institute, to whom was referred for examination the "Explosion of a Steam Boiler" at I. P. Morris & Co.'s, at Richmond, Philadelphia, report:

The boiler in question was cylindrical, 5 feet in diameter and 16 feet long, having a steam dome 4 feet in diameter, which was placed over an opening of the same size in the shell of the boiler. The iron was of the best quality, 0·3 inch in thickness, and was to be used under 100 pounds pressure. The parties who ordered it required that it should be tested under a pressure of 150 pounds. Upon this trial the fire was kept up until the safety valve lifted under a pressure of

148 pounds; an additional weight was then added, sufficient to give the requisite pressure of 150 pounds, and after a few moments the experiment was considered as satisfactory, and directions were given to open the fire doors. At this moment the explosion took place, killing one of the persons present and severely injuring two others, one of whom afterwards died.

The tensile strength of the shell of the boiler was found after the explosion to be 56,000 pounds per square inch of section, capable of withstanding 600 pounds to the square inch. But the committee says: "When we consider the effect of the large opening made into the steam dome, we shall see that the strength of the cylinder was very materially diminished, and probably brought below what was necessary to resist the strain upon it.

"It will be easily seen that the effect of such an opening thus covered must be to bring a greatly increased strain upon its edge where it intersects the upper line of the shell, while the dome itself gives but little aid in resisting this pressure, and if the deformation of the shape or a tear of the iron should be the consequence, the other result of the explosion might easily follow. The committee deem this defect of form to be so manifestly sufficient to account for the explosion that they do not think it necessary to advert to any other, *but strongly call the attention of boiler builders* (makers) *and engineers to the importance of avoiding such large openings in the shell in future.*" *

Man-holes and Necks.

All holes cut into the boiler shell are sources of weakness. (A man-hole should never be placed on the shell, if it is possible to get it into either head.)

This is best illustrated by a trial made by the Manchester Steam Users' Association, of Manchester, England, in 1876.

The association was asked to guarantee some of the "French," or "Elephant," boilers, analogous in construction to those in use in this city commonly called "Two-story," or "Righter," boilers (the latter being the name of the man who first used one of this form). Outside of a radius of 30 miles of this city they are scarcely known, and if the city of Philadelphia had never known them *there would be fewer widows and orphans.*

* The italics are our own.

The majority of boiler explosions in this city, and the most disastrous ones, can be attributed to this form of boiler.

Independent of their dangerous character, the efficiency of this form of boiler is much over-rated; the (steam) water evaporated by them only averages about seven pounds per pound of coal, and the steam is generally wet; this is, no doubt, due to a lack of proper circulation through the necks, which is shown by the violent oscillations of the water in the glass gauge, the level varying as much as six inches several times per second, when worked anywhere near their calculated capacity.

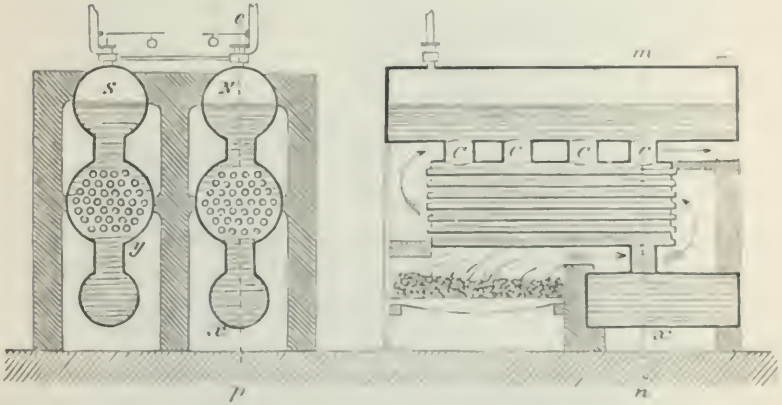


Fig. 5.

The last disastrous boiler explosion occurring in this city, from which four lives were lost, was a "Two-story" boiler, at the factory of Messrs. Wilt & Sons, which occurred June 29th, 1878.

To show the weakness of this form of boiler, I will state, for the information of those present, that the *factor of safety* recommended by the Franklin Institute, for the basis of estimate of the working strength of cylindrical surfaces of steam boilers should not *exceed* 6000 *pounds per square inch of section* (Franklin Institute Journal, August 16, 1873, page 142).

Or, in other words, the plates composing the shell of the boiler should not be subjected to more than 6000 pounds working pressure per square inch of section.

Now let us see how near this boiler corresponded to this.

The thickness of the iron in the shell containing the flues averaged 0·34 of an inch, the length of the shell being 144 inches (12 feet), of

which four holes, of 12 inches diameter each, or 48 inches, cut away for the necks, leaving only 144 — 48 = 96 inches by 0·34, equal 32·6 square inches, to resist a pressure of $\frac{144\times54\times80}{2} = 311{,}040$ pounds, which, divided by 32·6 = 9541 pounds per square inch, instead of 6000 pounds, as recommended by the Franklin Institute, an excess of $\frac{9541-6000\times100}{6000} = 59$ per cent.

p = steam pressure per square inch.
L = length of boiler, in inches.
l = length of boiler minus holes for necks.
D = diameter of boiler.
t = thickness of iron.
s = strain per square inch of section.

$$p = \frac{2\,s\,t\,l}{L\,D} \qquad D = \frac{2\,s\,t\,l}{L\,p} \qquad s = \frac{LDp}{2\,l\,t}$$

On April 25th, 1864, a "Two-story" boiler exploded at the factory of Cornelius & Baker, Cherry street, above Eighth, at 7½ A.M.

These boilers had been in use about two years and a half. Fig. 5 shows the boilers.

The writer was examined in regard to the cause of the explosion. In answer to a question as to the safe form of these boilers, my reply was: "*I am of the firm opinion they are not safe boilers.*"

The jury, in their verdict, say: "With regard to the form of the boiler and its liability to explosion, your jury believe, from the weight of the expert evidence brought before them, *that this form of boiler is not safe,** and that, by excessive firing and even moderately low water (we mean before the water has fallen so as to uncover any of the tubes), the water can be driven away from parts of the tubes, laying them bare for a time, and that upon any slacking of the fire and the return of the water upon the tubes, an undue strain will be brought to bear on the boiler.

"We think that the boiler is constructed on erroneous principles, for the following reasons: Granting that the cylindrical form of each part gives strength, *the cylinders are materially weakened by the holes made for the connecting necks.** * * * * *

* The italics are our own.

"We do not think this boiler has any claims for economy to compensate for its complicated form, and we judge that a single cylinder boiler, partly filled with tubes, with the water-line in the same cylinder, would be at once safer and more economical than this form of boiler. We are aware that many of these boilers are in use, and we would urge the greatest caution in their management. They may be moderately safe when the boiler capacity is large as compared with the work to be done, but are not safe when the consumption of steam requires heavy firing to keep up the pressure."

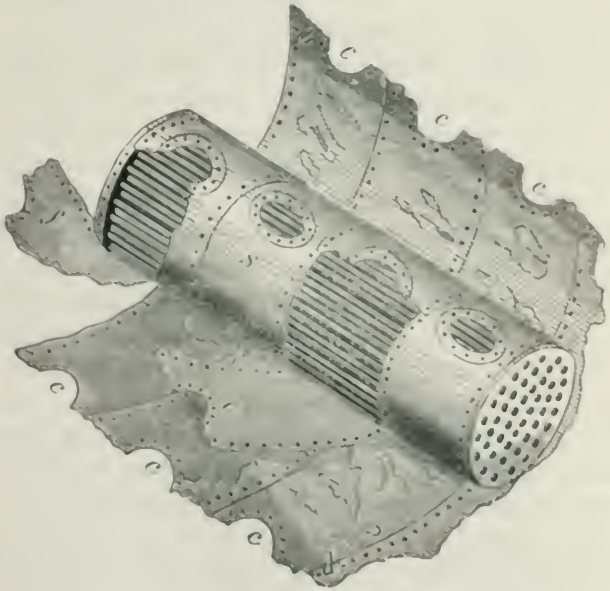


Fig. 54.

The flue shell of one of the boilers was torn wide open through the *weakest point*, to wit, *the necks*, c c c, as as seen in the above cut, and the other boiler fell into the former, in which position it was found after the explosion, and is also represented by the cut.

A two-story boiler exploded Oct. 4, 1860, at Preston's mill, Manayunk, killing the fireman.

To be continued.

OBSERVATIONS IN BRAZIL.

By W. Milnor Roberts, C. E.

[The Committee on Publication has been favored with the following letter from a fellow-member of the Institute, who is perhaps as well and widely known as any one of his profession in the United States.]

Rio de Janeiro, August 30, 1880.

My recollections of the Franklin Institute go back to its modest beginning, over half a century ago. Half a century—a long period in the life of an individual, though but a span in history—yet in that brief interval the Institute has accomplished a vast amount of solid, practical scientific work. Philadelphia as the central point, and the civilized world, owe a debt of gratitude to the pioneers who labored so earnestly and disinterestedly, under many difficulties, in establishing the Franklin Institute. The example of the Institute has been followed by numerous analogous societies in various parts of the United States. It has now many coadjutors in educating and stimulating the popular mind to scientific pursuits. How true the remark, "A drop of ink makes thousands, perhaps millions think." One good example becomes the fruitful parent of an endless succession. As an instance, Prof. Agassiz, with his scientific corps, visited Brazil from the United States and spent a few years in scientific examinations through this country. The leaven thus introduced gave an impetus to scientific studies here, and a number of young Brazilians have since been educated in the United States, while others have been taught in the polytechnic schools, which are now flourishing in Brazil. The English language is constantly becoming more popular, although French, the polite tongue of Continental Europe, still predominates among educated Brazilians, while the general language is Portuguese. The French metric system was introduced in Brazil subsequent to 1865, and it has been universally adopted by the government and upon all public works, and it is already popularized and used generally in the daily business of the cities.

The writer, with hundreds of others, has for many years used the decimal system in nearly all calculations, and he has advocated the system as the best for money, weights and measures. Of late years,

the metric system, notwithstanding some drawbacks, has appeared to offer the only practicable solution of this problem for general use throughout the world. The system works well in Brazil, but it is not so easy to make it work well in the United States and in Great Britain. It has seemed to the writer that the time had not arrived for making this system compulsory, excepting in government service, though it is perhaps approaching.

We have exploded the pound, shilling and pence in the United States, but we yet retain a host of confusing weights and measures. The tendency is to simplify calculation, but there is still a contest between the scientific advocates of the decimal, metric system and those who so extensively use the long-established fractional quantities of feet and inches and their multiples. There is also a contest between friends of the metric system, some urging immediate compulsory laws and others opposing the compulsory feature. The writer stands with the latter class, believing that the change—so radical a change as it is—should be gradual. The world is becoming more and more homogeneous, and it seems inevitable that, in time, one system of weights and measures must prevail throughout the civilized globe. But enough on this subject, which has come up only incidentally, though it refers to an important change that has taken place in Brazil within a few years.

The metric gauge has been introduced into their railway system, upon a number of lateral roads and upon some main lines, thereby creating a break of gauge, which must be remedied at some future time. It is true that the features and circumstances of this country are such that the construction of their 5 feet 3 inch gauge tracks becomes very costly, making unprofitable investments. Only a few steam railways here earn a profit upon their cost, and that is obtained through transportation charges four or five times greater than the charges common on railroads in the United States.

Interior wagon roads, such as are common all over the interior of our country, here dwindle to mule paths not far back from the coast, and former undertakings to extend turnpikes or macadamized roads through the interior involved almost as much cost per mile as the cost of railways. Hence the metric gauge railway is now the popular mode of developing new regions. They also adopt a high per cent. of gradient and sharp curves, and then procure Baldwin locomotives to run upon the tracks. The general government is now paying out

yearly large sums for interest guarantees on costly lines, some of which do not pay running expenses. American locomotives, and to some extent American cars, have been adopted on several lines, but there are others where only English locomotives and cars are used. The Brazilians are willing to adopt improvements in any kind of machine and machinery when they become convinced that they are actual improvements; it must, however, be kept in mind that nearly all the capital and the bulk of the engineering in Brazil have been supplied from England. The government guarantee of 7 per cent. per annum was very tempting to British capitalists. The active business men of the respective provinces in Brazil are not more averse to the expenditure of government funds in their particular districts than are the same class in the United States, but, here the resources are much more limited, and there is a constant tensile strain upon the national credit.

A new Ministry came into power a few months ago, and it is understood that "economy" is to be the order of the day, but sometimes the "Chambers," the Senate and Assembly have power to bend good pecuniary resolves. Governmental economy is certainly good, but it is a scarce article in most countries, outside of the speeches and addresses.

Brazil has had no canal era; she passed at a bound from mule-paths to railways. Nearly all of South America is well watered by rivers, some of them of great size; among them the Amazon, by far the largest river on the globe, the Parana, the Orinoco and the Sao Francisco. As yet they are as nature left them, except that there are settlements at intervals along their banks, and steamboats are plying on the lower portions; and in the case of the Amazon and the Parana, and some of their large tributaries, they are navigated for hundreds of miles above tide water, but, as the regions are but sparsely settled, the river commerce is irregular, and more precarious than it is on the navigable rivers of North America.

The San Francisco river is a very peculiar stream, being divided by the immense Paulo Affonso falls—nearly two hundred miles from the ocean, into the lower and upper river—separated by seventy-eight miles of entirely unnavigable rapids and falls. The total descent at the Paulo Affonso falls is two hundred and sixty feet in about three-fourths of a mile. The quantity of water, even in the low stage of the river, is very great, being about thirty-five thousand cubic feet per second. And yet, during the entire season of 1879, none of the tributaries, within a distance of six hundred and forty miles, contained

any flowing water at their mouths. The valley of this river is subject to long-continued droughts, so that, excepting along the banks of the river, where the soil is annually overflowed, there is scarcely any cultivation in the immediate valley. In this respect the San Francisco is different from the other large rivers of Brazil, which, usually, are blessed yearly with sufficient rain-fall throughout their valleys; but the most remarkable peculiarity of this river is its long stretch of good navigation, embracing eight hundred and twenty-four miles above the rapids. It is a beautiful stream; from a-half to three-fourths of a mile in width, and generally of ample depth; abounding in graceful curves, and dotted with cultivated islands, the greater portions of which are covered by annual floods, which range from twenty-five to forty feet in height. In many cases the houses, or "shelters," on the islands are quite temporary, and only used after the subsidence of the floods, the people retreating to their more substantial houses on the main land when the river rises, as it does during the southern summer, in December, January and February. These "more substantial houses" are, however, as a rule, very humble edifices, built of sticks and mud, one-storied, with tile or palm leaf roofs, with a door and one window without glass, an earthen floor and hooks on the walls upon which the hammocks are hung, with an absolute minimum of furniture, yet the half-breeds and the full-blooded population of Indians and negroes seem to be contented and happy. The percentage of whites among the population, excepting in the towns, is quite small. Nearly all of the land available for cultivation along the margins and on the islands has long been occupied, but, owing to the great cost of transporting their products to a market at the sea-coast, they raise very little more than they consume. This river valley has been occupied by this class of people for a hundred or a hundred and fifty years in different parts. They are all Catholics, originally Christianized by the Jesuits, who built numerous churches on the main land and on the more elevated parts of islands, some of which are now merely picturesque ruins.

The government is constructing a metric gauge railway, seventy-two miles long, around the Paulo Affonso falls, to connect the Upper and Lower river commercially. Above the upper terminus of the railway there are about two hundred and sixty miles of impassable rapids. It was this portion of the river that the writer more particularly examined and reported upon in 1879. When this part shall be improved, as it can be at moderate cost, the people of the Upper river will have a

practicable outlet to the sea-coast, the river below the falls and rapids being always navigable for small-sized ocean-going vessels, drawing ten to twelve feet of water.

There are some thirty towns along the banks of the San Francisco, varying in size from one hundred to eight hundred houses, a majority of the buildings answering to the preceding description. In the larger towns there are a few fair houses—some *sobrados*, or houses of two stories, and some with glass windows. "Numerous poor people, and a few well-to-do" will apply to any town on the Upper river. A little money goes a great way—and the river-traders go after it, and get it.

There is one very noted church on the right bank of this river, one thousand and thirty miles from the sea, called the "Senhora Bom Jesus da Lapa." It was originally an immense, natural cavern, at the end of a very peculiar *serra*, or mountain, of bare limestone, which, with little labor, was transformed into the most curiously picturesque church imaginable. The serra itself is quite unique, being a mass of gothic pinnacles about half a mile long and two hundred to two hundred and fifty feet high. A natural opening in the side of the mountain was filled with a large window, which lights the interior in a weird manner. From the high, rocky ceiling clear, sparkling water, in several places, is constantly dripping upon the rocky floor, where it stands in little pools. Pilgrims, from places hundreds of miles off, visit this celebrated church and deposit their offerings, and many carry away bottles of the water, which they believe to possess miraculous properties. In one part of the cave there is white carbonate of lime, little pieces of which are obtained and taken away as a cure for sore eyes. Individuals of families make vows that they will visit this church, even though months may be occupied going and returning, in order to secure the smiles of "Our Lady" and bring good fortune to the family. It has been a nucleus, around which have clustered several hundred houses, and at times there are hundreds of pilgrims in the place, nearly all of whom travel on the river in canoes. This church is one hundred and fifty years old.

There has been a steamboat on the "Clear river," as it is called, above the rapids, for eight years, but in 1879, when the writer, by permission, took possession of it, it had not been run for three years, and it had never made but three partial trips. Practically, therefore, steamboating has not yet been established on the upper river, although it was proven by the writer's expedition in 1879 that it is navigable

for steamers for eight hundred and twenty-four miles, up to the falls of Pirapora, seventeen miles above the junction of the Das Velhas and San Francisco rivers, thirteen hundred and eighteen miles from the sea. This steamboat is built of iron, with side-wheels, ninety-eight feet long, fourteen feet wide, draws about four feet of water, and runs three or four miles an hour against a two-mile-an-hour current. It was carried, in pieces, more than three hundred miles across a wild country of miserable roads or mule-paths, and put together at enormous cost. It is not at all adapted to the river; drawing too much water and not having enough power. Light-draught, stern-wheel boats, such as have been for years used on the interior rivers of the United States, are the kind suited to the upper San Francisco.

At present, the commerce of the river is carried on chiefly in "barcas," boats from fifty to seventy feet, or even more, in length, eight to fourteen feet beam, and drawing from three to five feet when loaded. These are polled up stream and rowed down stream. They have four, six, eight, ten or twelve hands, according to the size of the craft. They start at day-light and stop at dusk. These river-men are active and strong and manage their vessels with great skill. The plainest possible description of running down through the rapids, fifty-five in number, when the river is in moderate flood, is not a little exciting. In the hands of a regular writing traveler, like Captain Barton, the rapids are rendered highly romantic and fearfully interesting.*

This river being within eight to twenty degrees of the equator, the climate is of course warm; but the nights are almost invariably cool and pleasant, and the early mornings are sometimes uncomfortably cold. There is a breeze nearly all the time, and on some parts of it the wind is disagreeably strong. Mountains are in view most of the way, and occasionally the mountain chains come to the river, adding greatly to the beauty of the landscape; though there are intervals where only flat or very gently rolling land is in sight. The writer was several times strongly reminded of scenes along the Delaware, between Philadelphia and Trenton—with the buildings and fences omitted. The fencing between the little plantations on the river banks is of a very primitive character. Timber is scarce. The river abounds with very fine fish, different from any with which we are familiar in the United

* The writer's description of these rapids fills many pages of very dry reading, although they are all about running water.

States. There are also alligators, not of large size, generally five to six feet in length. River-hogs are quite common; and there are some otters, and beavers. Game, excepting ducks, is not very abundant. Snakes flourish well, though we saw but few alive. Monkeys are rather rare, immediately along the river; but flocks of parrots are numerous, and there are some fine singing birds. There are ostriches, and their eggs are good food. There are Brazilian tigers; but they are not numerous.

There are mountain masses of excellent iron ore, at several points along the river; and good limestone is convenient; but fuel is scarce, till the upper part of the river is approached. No coal has yet been discovered along this valley. Salt is manufactured in a crude way, on a small scale, at the little farms or plantations, by leaching the saline, alluvial earth, and then evaporating the water; but their best salt is imported from the coast, and carried by pack-animals hundreds of miles. At seasons when the river is in a good stage, some salt is packed across by land from the lower to the upper river, and shipped up the river in boats.

The two great confluents, the Das Velhas and San Francisco, have courses of about five hundred miles each above their junction, so that the total length of the main river is over eighteen hundred miles.

The Das Velhas has been navigated by another very small steamer, during a favorable stage of the river for several hundred miles, though the stream is much obstructed by rapids, but no steamer is now running, the small trade of the river is carried on by canoes and *ajojous*, or double canoes. The San Francisco, above the Falls of Pirapora, is much more obstructed by rapids, and its still smaller trade is confined to canoes.

Most of the region above the junction is mountainous, and covered with true forest, the chief settlements having been made in consequence of the working of the gold mines, which have been wrought many years. There are diamond workings also, but they do not yield so well as formerly.

There is always a sufficiency of rain for agricultural purposes in this upper region, and the soil is good, though during half the year the weather is very dry, but the upper streams never cease to flow, and in the lowest stage the quantity of water is large.

Excepting the necessities of the gold and diamond districts, there has been no inducement for extensive cultivation of the soil on these

upper waters on account of their great distance from the coast market.

The "Dom Pedro Segrenda" Railway is reaching out toward this region by an extension. Quite recently it was opened to Barbacena, about three hundred miles from Rio de Janeiro, a point within a hundred miles of the head waters of the San Francisco.

Since the Emperor's visit to the United States, in the Centennial year, during which he made numerous observations all over our country, he is more than ever inclined to encourage the development of Brazil, not only by railways, but by the improvement of her rivers and harbors, but at the present time the resources of Brazil are so tied up by obligations previously incurred that not much can be applied in new directions. Coffee and sugar are the two principal products; cotton, since the United States resumed its supremacy as a cotton raiser, has not been very profitable here, and but little is now grown.

Slavery still exists, although by an Imperial decree all children born of slave parents, since 1871, are free. Many years must elapse, as the law now stands, ere Brazil would be free, but it is more than probable that other laws will be enacted hastening the period. An effort has been made (by the late ministry) to inaugurate a system of Chinese coolie labor, and an ambassador was sent to China for the purpose of negotiating some arrangement in that connection. It will fail, either in its incipiency, or in its trial, if ever tried. The slave owners must teach their slaves how to be free. Brazil is not a country to "settle up" by immigration, like the United States; the introduction of a foreign population into this country is destined to be only very gradual.

Spanish Engineering.—The success of Director-General Ibanez, in his Spanish triangulation, has led to applications for his assistance in other fields of labor. He has lately visited Paris on business connected with the international committee of weights and measures, of which he is the president, and he is about going to Switzerland to make the necessary preparations for the measurement of a base line with his apparatus. This arrangement is the result of diplomatic negotiations between the Swiss and Spanish governments, and it involves a permission to employ such members of his engineering corps as Señor Ibanez may desire. The Spanish journals manifest a justifiable pride in the honors which have thus been conferred upon one of their leading engineers.—*La Gaceta Industrial.* C.

MODERN STEEL AS A STRUCTURAL MATERIAL.

By W. Worby Beaumont, C.E.

Read at the Meeting of the Society of Engineers, England, October 4, 1880.

The object of this paper is not to bring forward any new experiments on the properties of steel as employed in constructive work, but to invite discussion upon a few points which may occur to the engineer to whom it seems desirable to consider the relative advantages of mild steels and iron in some mechanical or constructive work. For several years the substitution of steel for iron in various structural work has occupied the attention of engineers and metallurgists, but the progress which has been made, compared with the hopes that were entertained when steel made by the Bessemer process became cheap enough to make its cost strength for strength comparable with that of iron, has not been great. There are classes of structures in which a reduction in weight would be a material advantage, even when attended with an increased total cost. In this direction, therefore, engineers turned their attention, with a view to the application of steel. The difficulties, however, which attended the manipulation and connection of steel in structures largely composed of plates checked its application. Many failures attended the attempts to use it, chiefly resulting from apparently anomalous behavior of the metal under what were considered similar conditions, but more, perhaps, owing to the special treatment which it required as compared with iron. Those who had been long accustomed to the manipulation of iron were unable to depart from past practice sufficiently to operate upon the new material with all the careful attention to its different properties which these demanded. Thus, although the difference in its behavior in the hands of the smith and plate worker, as compared with iron, was considered in several of the details of manipulation, certain other peculiarities were lost sight of in the assemblage of parts, which resulted in the destruction of work when almost completed. Even twenty years ago, before the modern cheap steels had been offered, steel made by the crucible process had been successfully employed on a small scale for boiler work. Very careful attention to the behavior of steel under treatment had no doubt been observed, as it might easily be on a small

scale; but when, some years after, attempts were made to use Bessemer steel for boiler and bridge work, difficulties arose, some of which were attributed to the nature of the material and some to the want of thorough care on the part of the workmen. Even when plates of this material cost more than iron for boiler construction, and very much more than iron for bridge and girder work, attempts were made to use it for the latter on account of the several advantages which would arise from a decrease in the permanent load of bridge structures. Failures, however, of parts of these structures, both before and after completion, due to the want of the observance of the special treatment which the material demanded, discouraged its employment. The endeavors of steel makers during the past few years have, therefore, been directed to the production of steel possessing properties so far similar to wrought iron that no great departure from the methods of working this material need be made. Apart from the frequent want of uniformity in the mechanical properties of the Bessemer steel plates of a few years ago, it generally exhibited an absence of toughness, which not only made it difficult of manipulation in the hands of the plate smith, but caused its destruction after being built into a structure. Its uncompromising rigidity rendered it incapable of accommodating itself to, and gradually eliminating from, itself, the residual strains originating in unequal heating and cooling, and also to the unequal strains visited upon it by other parts of a structure, of which it was made to form a part, either by riveting or other modes of connection. It was not that the steel did not appear to possess the qualities when tested in the testing machine, but its behavior was apparently different when employed in full size pieces or plates, from that exhibited when tested in small pieces in the machine. This difference indicated that there were differential internal molecular strains resident in the whole plate, which were eliminated when the same plate was cut into strips. This elimination, it was considered, could not take place in the whole plate on account of the harshness of its material. Annealing was resorted to, but only with partial success, the complex nature of the strains in a plate of the material, even when cooled slowly, being sufficient, when aggravated by extraneous strains, to cause its rupture.

The necessity of imparting to steel plates the toughness characteristic of good wrought iron has thus induced steel manufacturers to devote their attention to the production of steel possessing great duc-

tility. It is on this point that much might be said, because in the search for toughness the advantages which the employment of steel in some structures seemed at one time to promise, are being almost lost sight of. Not only are these advantages likely to be lost, but the great ductility being imparted to soft steels and ingot iron in search for this necessary toughness seems likely to give us a material inferior in some essential qualities to much of the wrought iron hitherto in use. Toughness in plates has not been obtained, but instead thereof great ductility attended with low elastic strength. It cannot be disputed that there are large quantities of mild steel plates produced which will stand all sorts of tests, necessary and unnecessary, and behave better in manipulation than even the best wrought irons. Such mild steel plates have many applications, but for many engineering purposes they fall very far short of the structural value of plates which might be fitly designated steel, in the sense in which that term was used a dozen years ago, when cheap steel promised to aid the engineer in reducing structural weights.

It may be premised that the structural value of a metal will be proportionate to the degree in which it combines high ultimate strength with high elastic limit and wide range of elastic and ductile extension, or in proportion to the relation in which it combines toughness with strength. Thus a metal which possesses high ultimate strength and high elastic limit with small ranges of extension, will not have great structural value, as it will not be capable of withstanding impact strains. Again, a metal possessing high ultimate strength with low elastic limit will have small value for structural purposes, as, though high ultimate strength is an essential property, the limit of elasticity determines in almost all cases the sectional area, and, therefore, weight of metal required for a given duty. A high elastic limit, with considerable elastic extension, must be obtained, combined with great toughness beyond that limit, or in other words, a high elastic limit must be attended by a considerable range of extension both within and beyond that limit, combined with high ultimate strength.

The tendency, however, in the production of the modern mild steels and ingot irons, which will eventually no doubt supplant wrought iron made by the puddling process, is to make a metal which is far from combining these properties in such relations that it is best suited for structural purposes, or so as to offer those advantages which were at one time supposed to be attainable by the use of steel.

The best index to the comparative structural value of different materials is probably that obtained by the application of Poncelet's formulæ as simplified and made applicable for practical purposes by Robert Mallet. This formulæ expresses by coefficients Tr and Tr and Tr^1 and Tr^1 the work done by an extending or compressing force upon an elastic prismatic body, at the point where its elasticity becomes permanently impaired, and its form distorted, and at the further point where rupture occurs, or, in other words, it expresses the balance in any material between strength and toughness, and was designed to give a more exact index to the structural value of materials than was given by the early experimenters down to the days of Telford, when the force necessary to produce rupture was alone considered. The formulæ are probably known to most of the members of the Society, having been given by Mallet in a paper "On the Coefficients of Elasticity and of Rupture in Wrought Iron," published in Vol. XVIII of the "Proceedings" of the Institution of Civil Engineers, and subsequently employed by Dr. Pole in his book on "Iron as a Material of Construction," but they may be repeated here.

Let L = the length of the prism;

l = the unit of length;

A = the transverse sectional area of the prism;

i = the extension, or compression which is proportionate to $\frac{l}{L}$;

P = the force of extension or compression which is proportionate to A; and

e = the elastic resistance which balances P, or the modulus of elasticity.

The force P is, of course, variable between o and i,

$$i = \frac{P\,L}{e\,A} \text{ and } P = \frac{e\,A}{L}\,i.$$

If x be any small extension, or compression less than the nth part of i, P corresponding to $x = \frac{e\,A}{L}\,x$. The work done in extending, or compressing through the infinitely small additional range Δx (assumed uniform) $= \frac{e\,A}{L}\,x\,\Delta x$, and the whole work done when $i =$ the

compression or extension at which the elasticity of the material is permanently changed, or the elastic limit reached, is

$$Te = \frac{e\,A}{L}\int_{o}^{i} x\,dx = \tfrac{1}{2}\,\frac{e\,A}{L}\,i^2,$$

or $Te = \frac{1}{2}\,e\,i^2$, or simply $= \frac{1}{2}\,Pi$;

for the unit of length and section. The value of the coefficient Tr is arrived at in the same way, by substituting the corresponding values for P and i due to the moment of crushing or of rupture. Thus for a material having under tensile strain an elastic limit P of 12 tons per square inch, an elastic extension e of 0·02 inch in a foot of length, and having an ultimate of 22 tons per square inch and a total extension of, say 1 inch, the coefficient

$$Te = \frac{P \times 2240 \times \overline{\frac{e}{12}}}{2}, \text{ or}$$

$$Te = \frac{12 \times 2240 \times \overline{\frac{0{\cdot}02}{12}}}{2} = 22{\cdot}31$$

$$\text{and } Tr = \frac{22 \times 2240 \times \overline{\frac{1{\cdot}0}{12}}}{2} = 2052{\cdot}5$$

while another material having an elastic limit of, say 14·22 tons, elastic extension 0·024 inch; ultimate strength, say 23 tons, and total extension of 1·6 inch in a foot, the coefficient $Te = 31{\cdot}8$ and Tr 3501.

In order to determine the relative structural values of several materials, it is thus necessary to take Te and Tr simultaneously into consideration, though Te is the coefficient of the greater importance in most structural work.

About a dozen years ago Bessemer metal was offered for bridge and ship construction which in the testing machine showed an ultimate tensile strength of from 34 to 40 tons per square inch, an elastic limit from 20 to 26 tons, and a range of ductile extension of from 10 to 18 per cent., while the tests of plates considered suitable for the shells or barrels of boilers showed figures not much lower than these. The failures which occasionally attended the application of this steel, however, discouraged the extension of its application by engineers, who hoped that greater uniformity in the mechanical properties of the metal would gradually be obtained by the steel makers. A steel of

somewhat lower tenacity and greater ductility, attended by greater uniformity in composition and behavior, was then produced, and this indicated that steel makers and engineers must look to steel of milder character for the removal of the difficulties which had attended the structural application of cheap steels, that is steels not produced by the crucible. The result of this was that engineers specifying steel for, say, bridge work stipulated that it should not possess more than a certain maximum tenacity, a reversal of the stipulation that had always and does obtain with respect to iron. As a further result of this, and to ensure that the harder steels of comparatively high tenacity, but less uncertain character, should not be used in the construction of bridges, the Board of Trade regulations upon the subject limited the tensile strain on any part of a structure to 7 tons per square inch. This has led to the endeavor on the part of all steel-makers to produce the very mild soft steels now largely used, some of which affords the engineer no help towards producing the lighter structures which a dozen years ago it was promised that steel would give them. Boiler shells must be made nearly or quite as thick as if they were constructed of iron.

As an instance in illustration reference may be made to the results of a series of experiments made on iron and mild steel, in order to determine their respective values for high-pressure boiler construction, and described by Mr. David Greig and Mr. Max Eyth in a paper read before the Institution of Mechanical Engineers, in June, 1879. Amongst other experiments, the mechanical properties of mild steel and Yorkshire plates under tensile strain were determined. The plates—both iron and steel—were obtained from Messrs. John Brown & Co. and Messrs. Cammel & Co. In the paper referred to the mean tensile strength, elastic limit and extension are given as follows:

	Ultimate strength.	Elastic limit.	Extension
	Tons per square inch.		per cent
Iron plates, . .	22·27	16·06	36·2
Steel plates, .	25·80	16·74	28·3

The extension given is in a length of 6 inches. If all reference to the secondary elastic limit, which may be induced by repeated application of strain up to and slightly exceeding the elastic limit of each preceding test, be omitted, it will be seen that the so-called steels, to which the above figures relate, present scarcely any structural advantage over iron. The elastic limit is nearly the same, and though its

ultimate strength is greater than that of the iron, its ductility, as shown by its range of extension, renders its greater ultimate strength of little value, for very long before it can be strained to that limit in any structure, it stretches so much that the accumulation of strain is prevented and this may be shown to take place in bridge as well as boiler structures. With respect to the latter, Messrs. Greig and Max Eyth observe that "the tensile and shearing strength of the material supplied for these tests by some of the most experienced makers of steel, and by them, no doubt, considered the best for the purpose, has in the experiments proved to be not more than 10 per cent. above that of the iron supplied at the same time, and its want of hardness, as distinct from tensile strength, has proved to be a very serious disadvantage in boiler work. What the trade now requires is a return to a harder material of increased tensile strength without losing the homogeneity which is at present obtained at the expense of hardness." Again, in speaking of the results of the test, under hydraulic pressure, of the complete boilers made of this steel, they say "the compression of the rivet and elongation of the rivet hole resulted invariably in leakage which prevented the necessary pressure from being obtained. Each rivet became its own safety valve, and the strain put on the weakest part never reached more than 70 per cent. of the breaking strain. This is the point where additional hardness of the material would be most useful, as it would prevent the opening of the rivet holes, which now makes a boiler useless long before the breaking strain is reached." This evidence is, therefore, to the effect that no structural advantage is obtained by the use of these steels in place of iron.

If we turn now to the results of tests, made by Mr. Kirkaldy, of Siemens' mild steel, we find that the mean results for plates of from 0·37 to 0·70 in thickness, annealed and unannealed, are as follows:

	Ultimate strength. Tons per square inch.	Elastic limit. Tons per square inch.	Extension per cent.
Unannealed, . .	31·02	14·50	23·4
Annealed, . .	28·84	12·84	24·6

From these figures it will be seen that though this material (like that used at Messrs. Fowler's Works) may be very safe, it presents little structural advantage over iron-plates, the limit of elasticity being low, permanent set taking place at as low as 12·84 tons per square inch when the plates are annealed. It is, however, observable that though the extension of this metal reaches a total of 24·6 per cent. it is less

than 11 per cent. annealed, and under 7 per cent. unannealed at a strain of 26·78 tons, thus indicating very considerable toughness and probably greater value as a structural material than that tested by Messrs. Greig and Max Eyth.

Material described still more recently gives the engineer even less of hope that the modern steels for structural purposes will enable him to produce structures much lighter than he can do with iron. It would even appear that greater hope of obtaining a material of high structural value is to be found in iron, for it was recently stated at a meeting of the Iron and Steel Institute by a member, that he had been experimenting with puddled iron, the elastic limit of which ranged from 19 tons to 20 tons, while its ultimate strength was 29 tons and its elongation between these strains was 23 per cent. in a length of 8 inches. The elongation within the elastic limit was not mentioned. Unless a higher elastic limit can be obtained no advantage in a structural sense is secured. High ultimate strength is a comparatively useless quality if the elastic limit is low, and great range of extension is also of no service. In bridge work a very high range of extension is useless, because the members under tension would elongate if strained beyond the elastic limit, to a greater extent than the members under compression would compress, and thus the structure would fail by the destruction of the balance in the disposition of the strains on the different parts. Even if the material showed a range of compression equal to its range of extension this would remain equally true, because in order to secure the necessary resistance to bending or buckling, members under compression must be of greater sectional area than is indicated by the static strain. Thus a higher elastic limit is the first essential in steel for structural purposes. This it appears can only be obtained by making the steel harder, which, by the Bessemer process at least, if not by other largely used processes, it seems cannot be secured without other attendant qualities or properties which make the material difficult to work, and more or less uncertain in its behavior under mechanical treatment. Whether this is really now so, or must continue so, it remains for the steel makers to show, but it does at least seem plain, that even with some of the so-called mild steels a little misgiving is pardonable on the part of the boiler maker, who wonders what he may find in a boiler shop to-morrow where he has left a nearly or quite finished boiler to-night. Not only, moreover, is this mild steel way of getting over the difficulties attending the use

of the strong steels likely to rob engineers of much that the latter material promised, but by the still existing custom of denominating what is really iron by the term steel, we are likely to use the advantages gained by using the harder steels where that has been possible, for already a good deal of so-called steel, in which there is not much more carbon than there is in a Lowmoor bar, is being worked up into steel rails and steel tires. It is true that rails of very hard steel do not wear quite so well as those of a tougher quality, but it remains to be seen whether some of the very mild metal being rolled into rolls to-day may not soon acquire battered heads under the heavy traffic of modern locomotives. Such rails will not laminate, but it is questionable whether splitting will not result from the deformation by battering.

It will have been observed that in this short paper the attention of the writer has been almost wholly confined to references to plates. This has been done because it is chiefly in plates that improvement has to be looked for from the steel maker. With bar steel, the difficulties in manipulation and connection in structures have not been so great as with plates, and failures, whether due to imposed or internal differential molecular strains, have not been so frequent; the sections are less in area and the forms less capable of initiating and transmiting destructive strains. Consequently mild bar steel need not be so ductile as mild plate steel, and hence the structural value of the former is much higher than that of plates, and engineers can use it to advantage. In the course of a very interesting lecture delivered by Dr. Siemens at the Royal United Service Institution in March, 1879, he gave a table showing the results of a series of tests of mild and hard steel bars up to, and slightly beyond, their elastic limit. This table is of great value as affording evidence of the structural value of these bars, and it is to be greatly desired that similar observations should be made on all kinds of modern metallic structural materials. The mild bars to which Dr. Siemens' table refers show a mean elastic limit of 17·37 tons when annealed, though the same bar showed the lowest mean elastic limit of 16·62 before being annealed, and curiously the elastic extension is also greater in the annealed bars, the mean extension in bars 5 feet 0 inches and 4 feet 11 inches, being 0·088 inch and 0·086 inch, the value of *Te* of the bars being by the before-mentioned formulæ, respectively 57·04 and 53·348. This denotes a high structural value although this indication must be taken with the value of *Tr* which cannot be gained from the table referred to. Such material, however,

is not to be had or cannot be safely used in plates, and even in bars has been very little used in bridge work. Steel makers have yet to satisfy engineers that it can be safely used.

The most of the recorded experimental results of tests of mild steels do not give the extension at the elastic limit, so that comparisons with other materials cannot at present be made. From what has been said, however, it will have been seen that it is very necessary that these figures should be obtained, and what has often been observed may be here repeated, namely, that in order to the production of a satisfactory series of tables of the mechanical properties of different structural metals, experiments should be conducted on a uniform basis and with uniform lengths of test pieces, or if not of uniform length, they should be of a minimum length of either ten inches or one foot. Such experiments would be perhaps costly, but there is at least one wealthy engineering society, by a committee of which such experiments might be usefully carried out on the structural materials of to-day.

In conclusion, a few words may be said upon the behavior of the harder kinds of steel plates in which they differ from those of iron. It has been observed by many that some of the steel plates with an elastic strength as high as 18 tons per square inch combined with a ductile extension as high as 15 per cent. as obtained by the tests of strips of such plates, that in the hands of plate-smiths or when built into structures, they behave very differently to iron with the same apparent mechanical properties. The toughness of good iron plates enables them gradually to dissipate any internal differential molecular strains of tension and compression that may be resident in them as they leave mills, by differential compression and tension. Steel plates which are comparatively hard, but, which, when torn asunder in test-strips, indicate an ultimate extension of as much as 15 per cent., might be expected to do the same. Such, however, is not the case, for the plate has often behaved when built up into a structure as though its ultimate extension was not more than one or two per cent., and like glass, possessed of high elastic limit but no toughness. Why this should be is not known, but it may be suggested that such being the behavior, the following may afford some clue to the fact that thick plates, at least of such material, have fractured in various directions, after the structure of which they have formed an integral part has been completed. Most plates before being built into a structure are annealed, but the following remarks apply equally whether annealed or not.

Plates when taken from the rolls or from the annealing oven are generally laid on a flat surface to cool, but whether laid down or stood on edge, cooling takes place somewhat more rapidly towards the corners and edges than at the middle. At first, the whole plate is of the same temperature, which may be that of redness. The exterior parts first assume the rigidity of cold steel, and contraction takes place on the interior parts which remain at a higher temperature, and therefore the contraction has taken place under a tensile strain. Thus, if a plate of 1 inch in thickness is considered in illustration, it will be seen that a corner of, say, 6 inches on either edge, has an area on the two sides of 36 square inches, but it has also the additional effective cooling area of the edges, which adds 12 square inches, making for a surface area of 36 square inches a total of 48 square inches of effective cooling area by radiation and evection. If, on the other hand, an area on the two sides at the centre of the plate, of 36 square inches of such surface, be taken into consideration, it will be seen that the edge surface can only be considered as cooling by conduction. Thus the effective cooling area of the outer parts of the plate is much more efficient than the central parts. These outer parts having, then, become rigid and contracted under tension, exert a correspondingly compressive strain upon the interior parts still at a higher temperature, and thus more or less amenable to compression. This tensile strain upon the outer parts or borders of the plate is gradually eliminated as the interior parts cool, and is finally changed into one of compression as the inner parts contract in cooling under a molecular tensile strain, due to the incapacity of the rigid border to follow the inner parts in the contraction. In the cold plate put into a structure, there is thus initial molecular strain differentiating from compression at the edges to tension towards the centre. If the plate is cooled under circumstances inducing unequal cooling, these internal strains are aggravated, and they may possibly be of such magnitude that extraneous strains, that would not materially affect a tough iron plate, may be sufficient in a harsh steel to cause rupture. Further, when a plate of such a character is being riveted up, every rivet is compressed under a very high strain to make it fill the holes, and thus acting as a viscous fluid, adds to the strains already tending to destroy the plate.

These remarks are only made as suggestions, and should perhaps have been put in the form of a question, as they are somewhat aside the object of this note, which is to invite discussion on what seems to

be the tendency in the production of very mild steel plates, namely, that in the endeavor to remove the difficulties which have attended the use of steel plates of high elastic limit, we seem to be in danger of losing the facilities for producing lighter structures which the application of steel seemed at one time to afford.

ON A PECULIAR BEHAVIOR OF COPPER.

By W. H. Preece.

Read before the British Association at Swansea, August, 1880.

In the preliminary experiments with the copper conductor, made by Dr. De la Rue and myself, to get everything in working order, it was noticed that in each case the effect of the first discharge was considerably smaller than in the subsequent ones, leading to the conclusion that the resistance of the conductors was affected by the powerful currents sent through them. The difference was so marked that no variation in the electromotive force of the battery or in the capacity of the condenser would account for it. Moreover, all the connections were so carefully made that nothing could account for the change but a variation in the resistance of the conductors.

Experiment 1.—A piece of ordinary gutta-percha covered wire, 30 feet long, was first used as a shunt to the galvanometer. A delicate Thomson's reflecting galvanometer (whose resistance was 5270ω) was joined up in circuit with a single cell of a battery, and a resistance of 100ω. Discharges were then sent through the wire, and the latter, after each discharge, connected to the galvanometer. No difference was observed in the readings taken before and after the discharges. Any alteration in the resistance, however minute, would have been visible in the readings of the galvanometer. The wire had been used for other purposes, and weak currents had been through it before. Hence it was thought that the effect might be evident only in virgin copper, that is, copper through which no current had previously passed.

To test this, three pieces of virgin copper wire—0·029, 0·049, 0·071 inches diameter—were obtained direct from the manufacturers, and used as shunt to the galvanometer previous to and after conveying the

powerful currents resulting from the discharge of 42·8 mf., charged by 3280 cells.

Experiment 2.—0·071 inch wire:

Previous to discharge,	210°
After first discharge,	210
" second "	173
" third "	153
" fourth "	150

The change was very marked.

Experiment 3.—0·049 inch wire:

Previous to discharge,	440°
After first discharge,	440
" second "	440
" third "	440
" fourth "	440

No change was observed.

Experiment 4.—0·029 inch wire (200ω resistance in circuit):

Previous to discharge,	630°
After first discharge,	630
" second "	615
" third "	615
" fourth "	610

Change was very slight.

Experiment 5.—The same experiments were performed with lead conductors, but without perceiving any change. Hence, while a considerable change of resistance was observable, the effect was very variable. The fact, however, is evident, that in some cases copper wire does not acquire its normal resistance until currents have passed through it. No definite conclusion or measurable results can be obtained from these experiments. Nevertheless, the phenomena were so decided and peculiar, that Dr. De la Rue and I propose to pursue the inquiry when foreign travel and seaside rest have restored our waning energies and replenished our scientific ardor.

ON THE LIQUEFACTION OF OZONE, AND ON ITS COLOR IN THE GASEOUS STATE.

By MM. P. Hautefeuille and J. Chappuis.

Ozone, as commonly prepared, possesses in oxygen so small a tension, 53 mm. at most, that its physical properties are scarcely known and distinguished from those of oxygen. We know the difficulties which M. Soret has so skillfully overcome in determining the density of ozone by operating upon oxygen slightly ozonized.

Among the physical constants of this body its formation-heat has been accurately determined by M. Berthelot, notwithstanding the degree of dilution in which it occurs when issuing from the effluve apparatus. The preparation of a mixture very rich in ozone is the first condition to be fulfilled in order to acquire new notions concerning this curious substance. We have formerly established that the isomeric transformation of oxygen submitted to the electric effluve follows simple laws, and that the proportion of ozone increases very little with the pressure for each temperature, whilst it is quintupled in passing from 20° to —55°. If withdrawn from the action of the electric discharges the mixture of ozone and oxygen ceases to be a homogeneous system in equilibrium. Nevertheless the mixture remains without appreciable alteration during the whole time that a constant temperature is maintained, operating below 0°. This relative stability of ozone has enabled us to compress the mixture, and to obtain tensions of ozone of several atmospheres.

As it is necessary to prepare the ozone designed for these experiments at the highest tension possible, oxygen must be ozonized at a very low temperature. Consequently it is kept for a quarter of an hour in an apparatus for alternative discharges, the slender concentric glass tubes of which are plunged in methyl-chloride; then it is caused to pass into the cylinder terminated by a capillary tube of Cailletet's apparatus. This reservoir, of about 60 cc. capacity, originally a vacuum, and kept at —23°, cannot be filled at once under a pressure bordering upon 760 mm., and is rapidly connected 5 times in succession with the effluve apparatus, the capacity of which cannot exceed 20 cc. In an hour and a quarter we succeed by this means in filling

the cylinder with a mixture of oxygen and ozone very rich in the latter gas.

The cylinder is then taken out of the methyl-chloride, and separated from the effluve apparatus by a stroke of the file; the gas which it contains is slowly driven back by means of mercury cooled down to 0° into the capillary tube, which is kept a —23°.

The mercury which transmits the action of the hydraulic press does not impoverish the gaseous mixture as rapidly as might be apprehended; there is formed on the surface of the metal a solid varnish, which rapidly limits the action; the heating of the gas during compression is more to be feared. Notwithstanding these difficulties we succeed in increasing the tension of the ozone in a very high proportion. From the first strokes of the piston the capillary tube becomes a sky-blue. This coloration becomes more marked in proportion as the volume of the gas is reduced, and if the tension of the gas is brought by compression to several atmospheres the gas is an indigo-blue, and the meniscus of mercury, seen through the gas, a steel-blue. The blue color of the gas becomes less intense, and the mercury resumes its ordinary metallic aspect when the tension of the ozone is diminished.

The above mixture contains enough ozone to permit the observation of a dense white mist at the moment of release after a compression of 75 atmospheres. It is therefore not necessary to compress ozonized oxygen as much as pure oxygen (300 atmos.), in order that a sudden release may occasion the momentary formation of a mist, the certain sign of liquefaction or even solidification. A comparative study of mixtures of oxygen and ozone, and of oxygen and carbonic acid, shows that under conditions which are fairly comparable the release must be stronger for ozone than for carbonic acid in order to make a mist appear. Ozone is therefore a little less easily liquefied than carbonic acid.

The mixture of oxygen and ozone, being an explosive gas, should always be compressed slowly and refrigerated. If these conditions are not observed the ozone is decomposed with the liberation of heat and light, and there is a strong detonation attended with a yellowish flash. M. Berthelot has shown that the transformation of oxygen into ozone absorbs 14·8 cals. per equivalent ($O_3 = 24$ grms.). Ozone therefore ranks among the explosive gases, and our experiments show that like them it is capable of a sudden decomposition. A part of these new facts may also be observed in oxygen which has been passed slowly

at common temperatures through an effluve apparatus. For if the gas is rapidly compressed in a capillary tube placed in water at 25° the ozone is often destroyed with explosion. But if the same gas is cooled down to —23° the ozone which it contains may be brought to a tension of 10 atmospheres, and may be preserved for hours under these conditions of pressure and temperature if the gas is separated from the mercury by a column of sulphuric acid. We observe then almost as distinctly as in the former experiment, which is more difficult to perform, that ozone is a gas of a beautiful sky-blue. Its color at a tenfold density is so intense that we have been able to see it in a tube of 0·001 metre in diameter when operating in a very badly lighted room of the laboratory of the Ecole Normale.

It is therefore ascertained that under a strong pressure ozone is a colored gas, but is it the same with ozone at the tension of a few millimetres? The blue color is as characteristic of ozone as its odor, for at all tensions it is recognized on examining a stratum of the gas of sufficient depth. In order to render it apparent it is merely needful to interpose between the eye and a white surface a tube of 1 metre long traversed by the current of oxygen which has passed through Berthelot's effluve apparatus. The color of the gas then resembles that of the sky, and is deeper or lighter according as the oxygen has remained a longer or shorter time in the apparatus, and is consequently more or less rich in ozone. As soon as the effluve is interrupted the blue color disappears, the ozonized oxygen being replaced by pure oxygen.—*Comptes Rendus.*

Siphons in Sewers.—In constructing sewers it is often necessary to lead them across the branch of a river or some other water course. The passage has usually been accomplished on the plan of M. Belgrand, by means of a submerged siphon. The sunken portion, however, often clogs, and even where Belgrand's cleansing sphere is introduced the visits and repairs are difficult and costly. Maurice Lecvy has introduced an elevated siphon, to carry the sewer waters from Bercy over the St. Martin canal. Water pipes and valves are connected with the summit of the siphon in such way as to act automatically whenever the movement of the sewage becomes sluggish, and the experiment has proved satisfactory and economical.—*Ann. des Ponts et Chauss.* C.

IMPROVEMENTS IN NICKEL-PLATING.

In nickel-plating the double salts of nickel and ammonia are generally employed—either the sulphate or the chloride—but these are not exactly satisfactory, and amongst recent improvements we notice those of Mr. J. Powell, of Cincinnati, which consists in forming nickel-plating solutions, whereby the difficulty of electrolysing certain acid or neutral nickel salts is entirely overcome. It is well known to electro-platers and others versed in the art, that the double salts of nickel as commonly used, such as the double sulphate of nickel and ammonia, or the double chloride of nickel and ammonia, or the double sellenate (*sic*) of nickel and ammonia, and other similar double salts, become altered in their proportions and undergo various changes dependent upon the power of the electric current or the length of time during which the solutions are subjected to its action. These changes are particularly liable to occur in such alkaline or neutral solutions as contain ammonia, from the fact that the ammonia is given off as a gas on the terminal poles in the solution. On the other hand, the simple acid salts of nickel have not hitherto been found to answer for the purpose of electro-deposition from the fact that such solutions refuse to yield a reguline or cohesive deposit of metallic nickel, but, on the contrary, such nickel solutions as the sulphate, the acetate, the sellenate, the chloride, the tartrate, the citrate and kindred salts invariably yield under the influence of the electric current a deposit more or less grey, powdery, or black, and having no adhesiveness or ductility whatever. This seems to be caused by the evolution of hydrogen and the deposit of a suboxide or subchloride, or other subsalts along with a certain proportion of metal. Mr. Powell has discovered by a series of investigations and experiments that the addition of benzoic acid to any of the salts of nickel (especially when a solution free from alkali is used) corrects in a marked degree this tendency to an imperfect deposit, and prevents the evolution of hydrogen, chlorine, oxygen, nitrogen and carbon, and consequently the formation of the subsalts referred to, and that which previously was wholly worthless as a depositing solution, and yielded a black powdery metal unfit for any practical purpose, when properly combined with benzoic acid, will then give a tough, cohesive and reguline deposit of a beautiful silvery-

white metallic nickel. The patentee has discovered, also, that such a solution becomes more stable in its character, the solution of the anodes keeping pace with the rapidity of the deposit, thus maintaining a constant density of the liquid under varied conditions of work. The amount of benzoic acid to be added is not arbitrary, but may vary from one-eighth of an ounce to one ounce of acid to each gallon of the solution, according to the nature of the solution employed; or the benzoic acid may be displaced by the "benzoates," as, for instance, the benzoate of nickel. The inventor has discovered, also, that benzoic acid is equally valuable as an ingredient in the solutions of other metals, as, for instance, the salts of cobalt, manganese, etc. He does not confine himself to any precise formula, so long as benzoic acid or its compounds makes a constituent of a depositing solution; but he prefers, among others, the following: To one gallon of pure water add 4 ounces of sulphate of nickel, 3 ounces of citrate of nickel, 1 ounce of benzoic acid; or the following formula may be used: To one gallon of pure water add 2 ounces of chloride of nickel, 2 ounces of citrate of nickel, 2 ounces of acetate of nickel, 2 ounces of phosphate of nickel, 1 ounce of benzoic acid; or the following: 3 ounces of sulphate of nickel, 3 ounces of citrate of nickel, 1 ounce of benzoate of nickel, ¼ ounce of free benzoic acid; or the following: 3 ounces of acetate of nickel, 3 ounces of citrate of nickel, 1 ounce of phosphate of nickel, 2 ounces of pyrophosphate of soda, 1 ounce of bisulphite of soda, 5 ounces of aqua ammonia, 16 per cent. The benzoic acid being sparingly soluble in water it is advisable to heat the other nickel salts in the proportion of water named, and then, while boiling hot, add the benzoic acid, which will in this state combine with the nickel salts in a greater degree than with water alone. A great advantage obtained from the use of the above described solutions arises from the fact that the necessity of using chemically pure salts or ingredients is dispensed with. In preparing the sulphate, citrate, acetate or chloride of nickel, it is preferred to take the common commercial acids to dissolve the nickel base because of their cheapness, the otherwise injurious effects caused by impurities always contained in said commercial salts or acids being entirely overcome by the addition of benzoic acid as stated. The patentee is thus enabled to produce nickel-plating solutions at a much less cost than has heretofore been attainable. It is obvious that these improved solutions are equally applicable to the deposition of nickel in the electrotype process, by which the metal is caused to deposit over

surfaces made conducting by means of a thin film of plumbago, bronze powder, etc., applied in the usual manner well known to electrotypers and others skilled in the art, the deposit so made being removable from the surface, mould or matrix after the requisite degree of thickness has been obtained. In such nickel-plating solutions as contain ammonia or other alkaline salts, it is preferred to combine with these, as giving the best results, the pyrophosphate of soda and the bisulphite of soda, because it has been discovered that the addition of these salts prevents the destructive decomposition to which such solutions are liable. Finally, salicene or salicylic acid and gallic or pyrogallic acid may be added to or substituted in any suitable proportions for the benzoic acid.—*English Mechanic.*

Safety Paper.—A bank in Lyons uses a paper which is colored with ultramarine green. The bills of exchange are lithographed, and the figures are written with an acidulated ink, so as to appear white upon a green ground. This seems to furnish a perfect security against alterations.—*Dingler's Journal.* C.

Electric Light in the French Salon.—The Palais de l'Industrie was lighted by the Jablochkoff method during the recent exhibition. There were 356 candles in all, the motive force being supplied by five engines and twenty Gramme machines. The effect upon the sculptures was uniformly pleasing. Some of the painters complained that the electric light made their pictures look unnatural by falsifying the colors, but while some of the paintings lost effect others gained it. The general public were so well satisfied as to throng the Salon in crowds every evening.—*Les Mondes.* C.

Maiche's Electrophone.—Experiments have been recently made in France with a new electrophone. A small glass case is enclosed in a wooden box. Upon the glass there are small cylinders of pure charcoal, and the vibrations are transmitted by a single telegraphic wire. The return current by the earth gives a better result than when two wires are employed. No mouthpiece is required, it being sufficient to speak in the neighborhood of the instrument. The inventor is confident that he will be able to send messages by the transatlantic cable between France and America.—*Ann. du Gen. Civ.* C

Magnesium in the Sun.—The intensity and the frequency of reversal of the magnesium rays, in the green region of the solar spectrum, has long attracted the attention of spectroscopists. It has also been observed that the reversal did not affect all the rays at the same time. Prof. Young has made extensive comparisons with the C ray of hydrogen, which is always reversed in the chromosphere; Lockyer has shown that the reversed rays are the longest, and that among the reversed rays that which is the least intense is also the shortest; Tacchini measures the variations of solar activity by the number and frequency of reversals, supposing that the most intense rays appear first and that the energy of the eruptions varies in proportion to the number of reversals. This inequality of reversal has led to the theory that all terrestrial elements are dissociated in the sun into other unknown elements which have more simple spectra than those which are known. This theory implies the impossibility of deducing the constitution of celestial bodies from the spectral study of terrestrial elements until they have been dissociated and their component elements have been recognized. Fievez has studied the spectra in various ways. He first examined the influence which the relative intensity of the brilliant magnesium rays exercised on their visibility by projecting them upon the solar spectrum and thus effecting a true reversal. He then repeated his experiments upon the simplification of spectra by varying the intensity of the spark. Finally, guided by Lord Rayleigh's investigations in spectral optics, he studied the influence of a dispersion and of a definition, more or less considerable, upon the number and visibility of the rays, by comparing prismatic and diffraction spectra. His experimental arrangements were the same as those which he adopted in his investigations upon the spectra of hydrogen and nitrogen. They seem to establish conclusively his opinion that a modification in the appearance of the spectrum springs from a physical cause and not from a change in the chemical constitution of the metal or or a dissociation, and that the unequal reversal of the magnesium rays is caused by a difference in the intensity of the brilliant rays and not by any special state of the metal.—*Bull. de l'Acad. de Belg.* C.

Punching Iron.—Tresca's experiments upon the flow of solids, and the experiments upon cold punching by Messrs. Hoopes and Townsend and Prof. Thurston, have induced Prof. Keller to make a

series of experiments in the machine shops of Carlsruhe. The pieces, after being punched, were cut and the surfaces treated with a solution of chloride of platinum in water, containing one part of the chloride for 250 to 300 parts of water in volume. The employment of this solution brings out the lines of flow in brown upon a ground of brilliant gray. The operation of punching is divided into two distinct periods. The first begins with a depression at the top, the displaced matter being carried towards the bottom in such manner that the sides, which are at first vertical and parallel, soon incline towards each other. In proportion as the punch advances the material turns towards the point of least resistance, forming a sort of button underneath, the height of which is always much less than the depth to which the punch has penetrated, showing that the metal has either been compressed or that it has been driven laterally into the body of the piece. Keller found by experiment that the specific gravity of the plug was a little less than that of the residue. This fact had been observed by Hoopes and Townsend, but they attributed it to errors of observation. If the plug is cut into sections the density is found to increase towards the top, showing that there is a flow from underneath the punch laterally into the mass of the iron. In the second period, or period of chiseling, the resistance is less; there is no more compression and the plug goes out in proportion to the descent of the punch until the separation is complete. By equating the resistance to compression at the end of the first period to the resistance to chiseling at the beginning of the second the author found for iron the following formula:

$$C = \frac{\delta^3}{1{\cdot}15}\left(1 - 1{\cdot}3\frac{D}{\delta} + 0{\cdot}42\left(\frac{D}{\delta}\right)^2\right)$$

in which C is the total apparent compression, D the diameter of the punch and δ the thickness of the plate. The work expended in punching, when referred to a square millimetre of cylindrical surface of the hole, was satisfactorily represented by Hartig's empirical formula

$$a = 0{\cdot}25 + 0{\cdot}0145\,\delta.$$

—*Bull. de la Soc. des Ing. et Arch. d'Autr.*

Printing Cable Dispatches.—Marquis Tomasi has succeeded in printing, with plain alphabetic letters, dispatches which had crossed the ocean by the trans-Atlantic cable, using only two cells of a Dinotto battery. There are still some irregularities and difficulties, which he hopes soon to overcome.—*Les Mondes* C.

Organic Synthesis.—About fifty years ago Woehler discovered that benzoic acid, when introduced into the digestive tube of man or animals, was transformed into hippuric acid. Other syntheses in the animal economy have been more recently discovered, and Baumann has recently shown that phenol and a number of other similar compounds are transformed into acid ethers.—*Ann. de Chim. et de Phys.* C.

Velocity of Steam Engines.—Prof. Von Reiche recommends as the most suitable velocity for the piston, $v = 1 \sqrt{p}$, p representing the absolute initial tension in atmospheres behind the piston. Prof. Werner recommends $v = 4{\cdot}2 \sqrt{s}$ for high pressure engines, and $v = 3 \sqrt{s}$ for condensing engines, s being the length of piston stroke. The latter rule appears preferable, because the most suitable piston velocity is greater in large engines than in small, under all circumstances, even when p has the same value. Gustav Schmidt recommends the equations $v = \frac{a\,s}{30}$ and $v = a\left(10 - \sqrt{N}\right)$; N being the effective horse power. The coefficient a varies with the rapidity of the motion of the engine, ·05 being very slow, ·07 slow, ·09 normal, ·11 quick, ·13 to ·20 very quick. Therefore, for a fifteen horse-power engine $v = 1{\cdot}25$ metres, while for a 150 horse-power engine $v = 2$ metres, at the normal velocity.—*Dingler's Journal.* C.

Philosophy of Welding.—If iron were similar to other bodies, and a blow or sudden pressure produced heat all through the mass, the unexpanded liquid at the surface, as well as the interior plastic iron already expanded, would rise in temperature, the consequence of which would be that the molecular conditions at the junctions would still differ, although both at a higher temperature, and therefore molecular union could not take place. But if the liquid iron at the surface of the weld is in that condition of temperature that it would cool by pressure, the result is different, as the blow or pressure acts on the plastic iron to produce heat, and on the surface iron—which is on the border-land between liquidity and plasticity—to produce cold; consequently there is a moment when the temperatures of the two would meet each other and render the molecular condition of the junction uniform and continuous. This appears to be a satisfactory explanation of the wonderful property of welding iron, and its counterpart in ice is the interesting phenomenon of "regelation."*L'Ing. Univ.* C.

Electric Adhesion of Metal Contacts.—A. Stroh has experimented upon the adhesion of two metals in mutual contact during the passage of an electric current. The adhesion is manifested most strikingly when the metals touch upon two edges crosswise; it changes with the nature of the metal. Stroh attributed the adhesion to a superficial melting and welding, which can be perceived by a microscope.—*Dingler's Journal.* C.

Human Power for Short Intervals.—At a late national trial of fire engines Prof. Hartig made some valuable experiments upon the amount of strength that could be exerted, for a short period, at the engine bar. The engines were worked by foot soldiers, on a warm day, and under an exposure to the direct rays of the sun. The mean velocity of the handles was 1·77 metres per second; the mean value of the effective work for each man 22·58 kilogrammetres per second, or about 4·1 times the value which Morin and Weisbach assumed for the average of eight hours' continuous labor.—*Dingler's Journal.* C.

Heats of Combustion.—Herr Thomsen has published in the proceedings of the Berlin Chemical Society the results of his experiments upon the heat of combustion of carbonated gases and of cyanic compounds. These publications are posterior to those which were made by Berthelot, and they confirm in a remarkable manner the results which were obtained by the French chemist. They are specially important in consequence of their having removed the last traces of the error which had been made in estimating the heat of formation of ammonia and, consequently, of all other bodies which are associated with it.—*Comptes Rendus.* C.

Collodion Tablets.—Schippang and Wehenkel dissolve gun cotton in the usual way in ether and alcohol, evaporate the solvent and press the residuum into tablets, under a pressure of about two atmospheres. These plates, which are called *collodolith*, resemble glass in appearance, burn slowly when they are held in a flame, and resist all atmospheric influences. Sometimes iodine and bromine salts are mixed with the collodion. Many of these plates are laid upon one another and then wrapped in sheets of pure collodion so as to be protected against external influences. This iodocollodolith can be used at any time for photographic purposes,—*Dingler's Journal,* C.

Franklin Institute.

HALL OF THE INSTITUTE, October 20th, 1880.

The stated meeting was called to order at 8 o'clock P.M., the President, Mr. William P. Tatham, in the chair.

There were present 105 members and 16 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that two persons were elected members of the Institute at their last meeting.

The Secretary reported the following donations to the Library.

British Patents. Vols. 22 to 33. 1879.

British Patents. Abridgments relating to Carriages. 1625 to 1866. London, 1880.

British Patents. Abridgments relating to Farriery. Part 2. 1867 to 1876. London, 1880.

British Patents. Abridgments—Electricity and Magnetism. Div. 4. Parts 1 and 2. 1839 to 1876. London, 1880.

Disclaimers of Patents. 1872, No. 916; 1873, No. 1040; 1877, No. 4647; 1878, Nos. 563, 624, 729; 1879, Nos. 57, 1226, 2447, 3230. From the Commissioners of Patents, London.

Textile Manufacturers' Directory of the United States. 1880. From National Association of Wool Manuf., Boston.

Aids to the Study and Forecast of the Weather. By W. C. Ley. London, 1880.
From the Meteorological Committee of the Royal Society.

United States Coast and Geodetic Survey. Methods and Results on a Physical Survey of the Delaware River. From the Survey.

Reports of the Secretary of War for 1874. From the Secretary.

"Gregory's Perfect Combustion Furnace" was exhibited in model and by diagrams on the screen. Mr. C. H. Towne described the action of the furnace, the chief feature of which was an arrangement of air passages leading to the point of exit of the gases of combustion from the furnace, the inventor claiming that by furnishing a full supply of oxygen under these conditions perfect combustion was secured. The coal is continuously fed to the combustion chamber through a hopper. Mr. Towne stated that the inventor had an experimental furnace built on

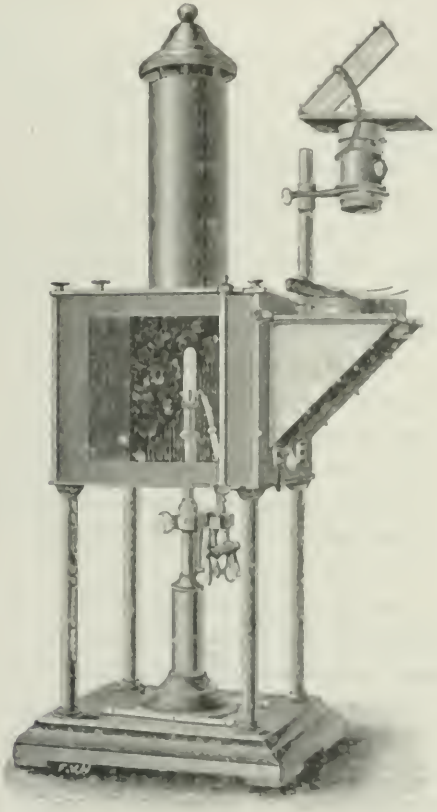
this principle, in which refuse coal, rubbish of all kinds, garbage, etc., had been consumed without smoke or offensive odors, showing perfect combustion. Economy was claimed on this account, but Mr. Towne, in answer to questions, said that he could give no precise data showing the results obtained.

Mr. Nystrom volunteered to explain the diagram, showing how the heat developed could be utilized under a boiler or to warm houses, a point not mentioned by Mr. Towne. He said that the idea of the furnace was not entirely new, similar forms being now in use for making steam, though the arrangement of parts was not the same.

Mr. Hector Orr exhibited samples of Toye's Multitint Printing, and briefly described what he considered a very important invention. He said that it could be applied to the printing of paper, cloth, morocco, etc., and used for decorating sheet metal, fancy woods for mosaic tables and various other substances which it might be desirable to ornament in large quantities. In this invention we have the means of drawing fresh tribute to Philadelphia, and the Institute could trust the inventor, now that the principle had been shown to be right, to perfect the machines that might be needed to apply it to any desired end. The samples of multitint printing shown by Mr. Orr were marbled surfaces of paper and cloth, in various colors, and used as the groundwork for printing cards, etc.

The Secretary's report includes an account of Queen's new College Projector, which is an optical lantern in its most perfect form, combining the horizontal and vertical positions, and especially adapted for the illustration of the laws of light, sound, and for chemical experiments. To accomplish this, the brass body is rigidly held together by thumb-screws at the top, and is supported on four pillars, at an elevation of about one foot, fitting it for the reception of either an electric lamp or an oxyhydrogen lime jet. The brass body is 11 inches long, 9 high and 8 wide, and is furnished with doors on either side, and a tall chimney to carry off any heat. To the front inside is attached the collecting lens of the condenser, the condensing lens being set in a collar on the flap or door hinged on the outside. This collar supports a bar, carrying the object glass and one of Foucault's mirrors, all being capable of being rotated around the optical axis of the instrument. When it is used as a vertical lantern, the flap is raised to a horizontal position, and is supported by the brass prism inclosing the reflector. All the optical combinations have been determined, after

long and careful experiment, so as to project a sharp, well defined and flat image on the screen. As the oxyhydrogen jet is specially adapted, also, to the focus of this lantern, an excellent illumination is obtained.



To show the qualities of the projector, a set of König's wave apparatus plates were exhibited. These glass disks, with black surfaces, have lines traced upon them, in such a way that when revolved before the lantern (a metallic screen, with a number of fine vertical slits, being interposed) wave motions of condensation, rarefaction, etc., were reproduced in moving points of light, in the most perfect way, upon the screen.

Harris' Fire Escape and Hose Elevator, a model of which was shown, consists of a suitable carriage and three ladders, which are supported in the vertical position when in use by bridges, at different

heights, resting on them. The outer ones are hinged to the carriage, and all three ladders readily lie upon it when not in use. The hose is also easily elevated to any particular point, and the firemen can pass on the bridges to where their services are most needed.

Dwight's Car Pusher, one of which was shown, is made entirely of steel, and consists of a bed-plate or shoe, which is placed on the track, and a lever hinged to it, by which considerable power is obtained. It will not slip on ice, and when the lever is applied to one of the wheels a man can readily move a loaded car.

Attention was called to Beck's New International Microscope, which has a tripod for its base, upon which is placed a revolving fitting, graduated to degrees, by which means the microscope can be turned round without its being lifted from the table, and the amount of such rotation registered; upon this fitting two pillars are firmly fixed, and between them the limb can be elevated or depressed to any angle, and tightened in its position by a lever. The limb carries at one end the tube (binocular or monocular), with eye-pieces and object-glasses. In its centre is the compound stage, beneath which is a circular plate, sliding on a dove-tailed fitting, and moved up and down by a lever, carrying the supplementary body or sub-stage, and at the lower end a triangular bar, carrying the mirror.

The binocular body has the ordinary Werham prism, for the purpose of dividing the rays, and the upper or eye-piece ends of the tubes are fitted with racks and pinion for varying the distances between the two eye-pieces, to suit the differences between the eyes of various persons, and arrangements are made for racking out one tube more than the other, to suit irregularities or inequalities between the eyes of the observer. This body is moved up and down with a quick movement, by means of milled heads, and also with a very delicate and fine adjustment. This milled head works against a lever, which moves a slide independent of the rack-movement, and gives an adjustment at once certain and decided.

The compound stage is of an entirely new construction; the object is most frequently merely placed upon it, but, if necessary, it can be clamped by carefully bringing down a spring-piece. The ledge will also slide up or down, and the object may be pushed sideways. This arrangement forms the coarse adjustment. Finer movements in vertical and horizontal directions are effected by means of two milled heads, the screws attached to which are kept up to their work by

opposing springs, so as to avoid all strain or loss of time. The whole stage revolves in a circular ring by a milled head, or this can be drawn out, and then it turns rapidly by merely applying the fingers to the two ivory studs fastened on the top plate, which is divided into degrees to register the amount of revolution. The stage is attached to the limb on a pivot, and can be rotated to any angle, which angle is recorded on a divided plate or can be turned completely over, so that the object can be viewed by light of any obliquity without any interference from the thickness of the stage.

Beneath and attached to the stage is an iris diaphragm, which can be altogether removed from its dove-tailed fitting, so as not to interfere during the rotation of the stage. The variations in the aperture of this diaphragm are made by a pinion working into a racked arc and adjusted by a milled head.

Beneath the stage are two triangular bars, the one revolving round and the other rigid in the optical axis of the instrument. On the former the sub-stage, carrying all the apparatus for illumination and polarization, fits, and is racked up and down by a milled head; the mirror, also, if desired, slides on the same bar; the revolving motion to this bar is given by a milled head, and the amount of angular movement is recorded on the circle, whilst the whole of this part of the stand is raised and lowered concentric with the optical axis of the instrument by a lever and the amount of such elevation or depression registered on a scale attached to the limb. This bar can be carried round and above the stage, and be thus used for opaque illumination.

The lower triangle bar carries the mirror or a right-angle prism, when the illumination is required to be concentric with the optical axis of the instrument, and independent of the movements of other illuminating apparatus.

The mirror-box contains two mirrors, one flat and the other concave; it swings in a rotating semicircle attached to a lengthening bar, which enables it to be turned from one side to the other, and revolves on a circular fitting for giving greater facilities in regulating the direction of the beam of light reflected, the whole sliding on either of the triangle bars, previously referred to, and made to reverse in the socket so as to bring the centre of the mirror concentric with the axis of the microscope in either case.

As the mirror alone is insufficient for many kinds of illumination,

some provision has to be made for holding various pieces of apparatus between the object and the mirror. For this purpose a supplementary body, or sub-stage, is mounted perfectly true with the body, and is moved up and down in its fitting by rack and pinion connected with milled heads. This sub-stage is now regarded as one of the most important parts of the achromatic microscope; in it all the varied appliances for modifying the character and direction of the light are fitted. But a few years since it was considered sufficient for this part of the stand to be constructed so as to move up and down perfectly coincident with the optical axis of the instrument, and for that purpose it was racked in a groove planed out on the same limb as that on the upper end of which the optical portions were carried. But lately microscopists have shown the desirability of affording every facility for lateral angular adjustments; and this has led to the sub-stage being attached to an arc working in the circular plate, and moved by a rack and pinion, whilst the amount of such angular movement is recorded on the upper surface of the plate. Having once fixed the angular direction of the light, the focusing of it depends upon a lever which moves the circle up and down, and with it the arm carrying the illuminating apparatus, *in the optical axis of the instrument.* So long ago as 1854, Mr. Grubb, of Dublin, called attention to the advantage of mounting the illuminating apparatus on a revolving arm or arc, which he thus describes in his provisional specification for improvements in microscopes, No. 1477, 5th July, 1854: "My third improvement consists in the addition of a graduated sectorial arc to microscope concentric to the plane of the object '*in situ*,' on which either the aforesaid prism or other suitable illuminator is made to slide, thereby producing every kind of illumination required for microscopic examination, and also the means of registering or applying any definite angle of illumination at pleasure." With but slight modification, this is the plan adopted in this stand.

The sub-stage is also fitted with complete centering and rotating adjustments, the latter having a graduated circle attached, and fittings for carrying Darker's series of selenites, blue glass disks for modifying the light, etc.

The microscope was upon exhibition, and its peculiar stage movement and iris diaphragm attracted much attention.

Upon motion, the Institute adjourned.

Isaac Norris, M.D., *Secretary.*

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ACCOUNT OF VINCOTTE'S EXPERIMENTS MADE AT WILLEBROEK, BELGIUM, ON A TUBULOUS BOILER, WITH SEMI-BITUMINOUS COAL.

By Chief-Engineer ISHERWOOD, United States Navy.

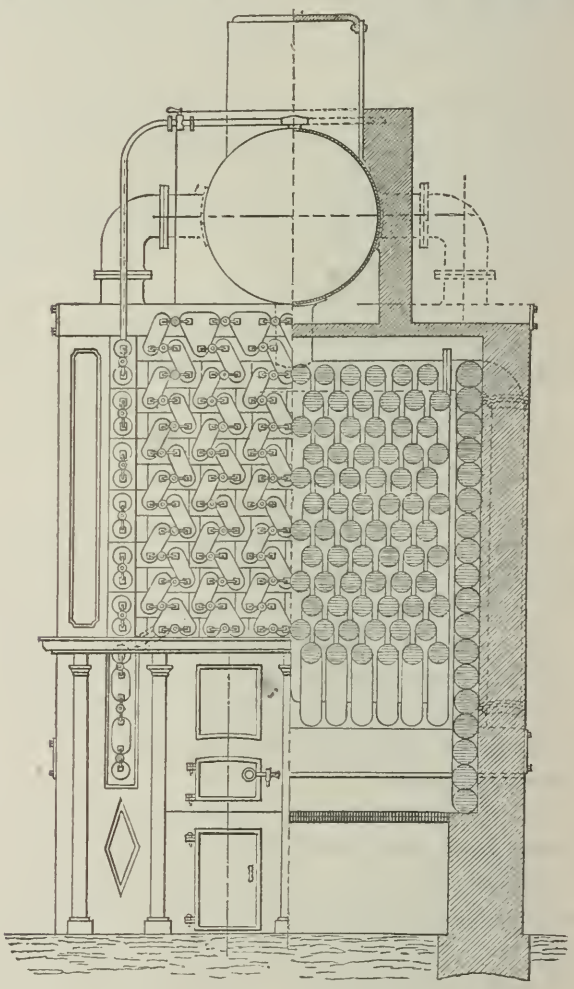
During the session of the third Congress of the Engineers-in-Chief of the Associations of the Proprietors of Steam Apparatus, held in Paris on the 7th, 8th, 9th and 10th of July, 1878, at the rooms of the Parisian Association, Mr. Vincotte, the Engineer-in-Chief of the Belgian Association, presented a paper on some experiments he had made with a tubulous boiler in the establishment of Mr. Denayer, at Willebroek, for the purpose of ascertaining its economic vaporization with semi-bituminous coal.

As this boiler is of a type not much used, and with which but very few experiments have been made, presenting, also, wide differences in its principles of design and construction from those commonly employed, I considered the subject of sufficient engineering interest to the readers of the JOURNAL to take from Mr. Vincotte's paper all the observed data, and from them to re-calculate, independently, the results in the manner found by English-speaking engineers the most convenient for practical purposes. I have given, likewise, a description of the boiler

and a calculation of its elements not in the original paper, and I have added my own remarks.

Boiler.

The boiler is composed of an assemblage of inclined water-tubes placed along the sides of and above the fire-grate, together with their



Half elevation. Cross Section.

connections; the whole being enclosed in a rectangular casing of brick masonry. The entire heating surface consists of the tubes and the

inmost sides of their connecting boxes, all of which are completely filled with water. There is no steam-superheating surface.

The steam-room is contained in a large horizontal cylinder lying immediately over the tubes and separated from them by a vaulting of brick masonry sustained on H iron girders. This cylinder is also enclosed by a rectangular casing of brick masonry; and, upon its upper side, at the front end, is a small steam-drum in the form of a vertical cylinder. The interiors of the large horizontal and the small vertical cylinders are in common, and the steam-pipe is carried from the top of the latter to the engine.

There is one furnace with a rectangular grate, and it is fired through two doors in the front, the opening for each of which is 8 inches high and 14 inches wide. The thickness of the wall through which these openings are made is 15 inches. The grate is 6·562 feet long and 6·168 feet broad, with the grate-bars in two equal lengths. The top of the grate inclines downwards 8 inches at the back, where the bridge-wall of brick masonry, 9 inches thick, rises 7 inches above it.

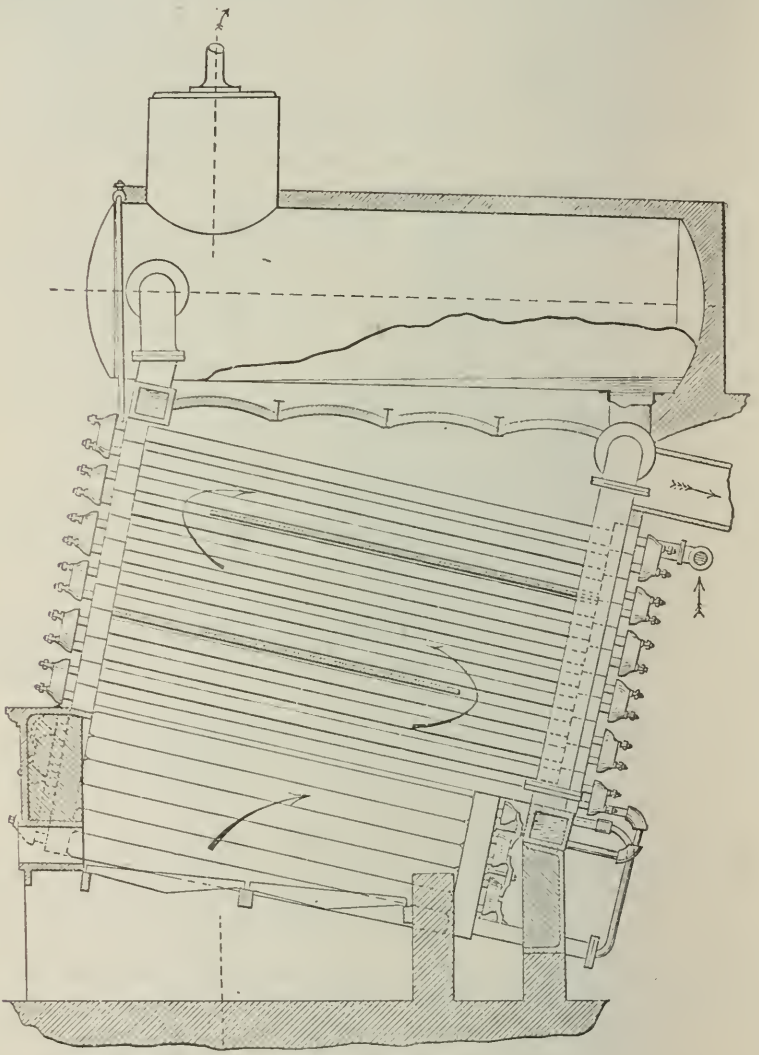
The bottom of the ashpit at the front of the furnace is 2 feet 8 inches, and at the back of the furnace 2 feet, below the top of the grate. The back, sides and bottom of the ashpit are of brick masonry; the side walls are 18 inches thick and the back wall is 9 inches thick. The front of the ashpit is closed by cast iron doors.

Between the back of the bridge-wall and the back wall of the boiler is an enclosed space 6·168 feet broad and 17 inches long lengthwise the boiler.

The height from the top of the grate to the lower side of the lower row of tubes above it is, at the front of the grate 37⅞ inches, and at the back 30¾ inches.

At each side of the grate, and extending from its top to the top of the assemblage of tubes lying over it, is a vertical row of 18 inclined wrought iron water-tubes, making 36 tubes for the two sides, 5¼ inches in outer diameter and 5¼ inches in inner diameter. These tubes are placed one upon the other without any intervening spaces, so that they touch along their whole length. The lower 6 of these tubes on each side are 7½ feet long, and the remaining 12 are 9½ feet long. They rest on a 5 inches offset in the brick wall at the side of the furnace, which wall is thence carried up 12 inches thick to the top of the boiler, the inside face of the wall and the outer ends of the horizontal diameter of the tubes touching, so that the tubes are in contact with

the wall and form a lining for it, which leaves only their inner semi-circumferences to act as heating surface. These tubes are united in pairs, alternately, at both ends, by connecting boxes of ordinary cast



Longitudinal section.

iron or of malleable cast iron, by which means the interiors of all are in common. The topmost tube on each side receives the feed-water

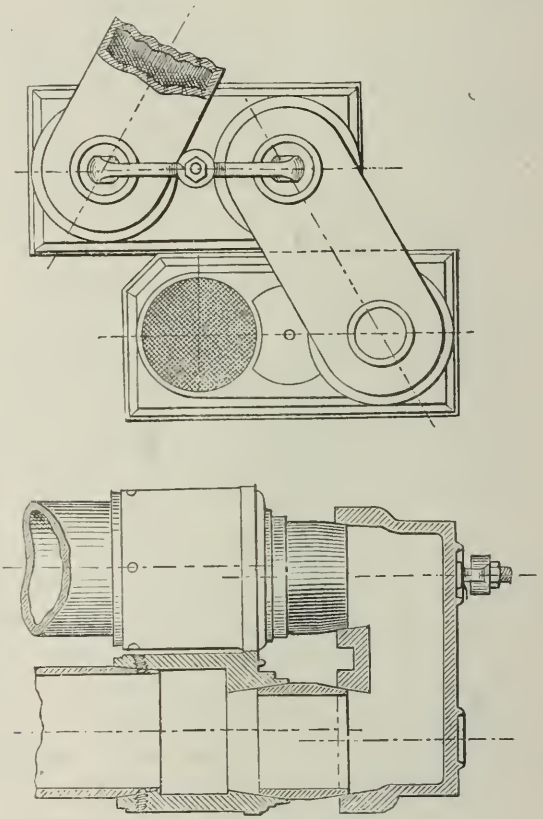
which traverses in succession all the remaining 17 tubes beneath it, and is delivered at the back end of the lowest tube into a lower cast iron box of rectangular cross section lying horizontally across the whole breadth of the boiler at its back. This box is 10 inches square on the outside, 7 inches square on the inside, and of 9 feet 2¼ inches extreme length; it is supported upon the 10 inches thick back brick wall of the boiler.

Immediately over the fire-grate, and lying between the two vertical rows of tubes just described, are 144 inclined wrought iron water-tubes of 4¾ inches outer diameter, 4½ inches inner diameter and 9½ feet length. All these tubes are parallel to each other and to the tubes at the sides of the furnace. The declination from the front to the back ends of the tubes is 22 inches in a horizontal length of 110 inches, or 1 in 5. The tubes are arranged in twelve rows horizontally and twelve rows vertically. The centres of the tubes of each of the horizontal rows are in the same straight line, but the tubes of the vertical rows are zig-zagged, the centres of the tubes of each of these rows being over the centres of the spaces between the tubes of the horizontal rows immediately above and below. The least distance between the tubes horizontally in the clear is $1\frac{5}{8}$ inches. The distance from the bottom of the tubes of the lower row to the top of the tubes of the upper row, measured at right angles to the axes of the tubes, is 5¼ feet.

The back ends of all the tubes of the lower horizontal row are secured into the inner side of the lower cast iron box already described of 10 inches square cross section and 9 feet 2¼ inches extreme length, whence they receive the feed-water, each tube of this row receiving the water simultaneously, which thence ascends, by suitable connections, the tubes of each vertical row in succession, passing alternately from back to front and from front to back until it emerges simultaneously from all the tubes of the upper horizontal row into an upper horizontal cast iron box of exactly the same dimensions as the lower one already described, which upper box is supported on the top of the front wall of the boiler.

The tubes of each horizontal row are secured in pairs—two adjacent tubes constituting a pair—into the inner side of a rectangular box of ordinary cast iron or malleable cast iron. The outside dimensions of each of these boxes are 11·81 inches wide, 5·91 inches high and 5·04 inches long lengthwise the boiler; least thickness of metal, ¾ inch.

These boxes being piled one upon another, and all in contact, like bricks in a wall, form the front and back walls of the boiler for the height occupied by the tubes. These fixed boxes are connected on their outside, vertically, by movable cast iron boxes, rectangular in cross section, and held in position by cross-bars secured by bolt and nut after the manner of securing manhole plates in a boiler. Every



Method of connecting Tubes.

two vertically adjacent fixed boxes, at front and rear of boiler, are connected by one movable box, which being taken off with the same degree of labor required for removing a manhole plate, exposes the interior of two tubes for examination and cleaning. In outer cross section, the movable boxes are 4·13 inches wide and 3·86 inches deep; least thickness of metal, $\frac{5}{8}$ inch.

The joints between the fixed and movable boxes are made by means of a wrought iron thimble 3¼ inches long and 3·39 inches inner diameter, the outer side of the thimble forming two frustra of cones united at their bases. The holes in the boxes for receiving these thimbles being made of corresponding bevel to the frustra, the cross-bar, bolt and nut force the beveled surfaces into metallic contact, and thus form a joint water-tight under the boiler pressure.

By means of these combined fixed and movable boxes, the water ascends from the lower horizontal cast iron box of 10 inches square cross section and 9 feet 2½ inches length to the upper horizontal cast iron box of the same dimensions, by passing alternately forwards and backwards through the intervening tubes, ascending simultaneously each vertical row of tubes. The combined fixed and movable boxes answer exactly the same purpose as the cast iron bends with ordinary steam-heaters for rooms, with the advantage of easy separation.

All the tubes are roofed over by a brick vaulting 2½ inches thick, supported on iron girders of H cross section. This vaulting extends from the front to the back wall, and between the side walls of the boiler, thus completing the entire enclosure of the tubes and furnace. A horizontal wrought iron conduit carries the gases of combustion from the top of the back end of this enclosure to the chimney.

Immediately above the vaulting is a large horizontal wrought iron cylinder, with segments of spheres for ends. The cylindrical part is 41 inches in external diameter and 11½ feet in length. The axis is in the vertical plane passing longitudinally through the centre of the boiler; and the cylinder, with the exception of the front end, is encased in brick masonry the outside of which is rectangular.

At the front end of this large horizontal cylinder and upon its top is a small vertical wrought iron cylindrical steam-drum of 31½ inches diameter and 27½ inches height, with a flat top, from which the steam is taken to the engine. Only the lower portion of this steam-drum to a small extent is cased in masonry. The object of carrying up this small steam-drum was to obtain height of steam-room to insure a supply of dry steam.

The interiors of both cylinders are in common and constitute the steam-room, which was of very great capacity proportionally to the capacity of the engine cylinder and its speed of piston. A small portion of the lower part of the large cylinder is occupied by water,

which, entering at the front end with the steam, passes out at the back end by a pipe to be described.

The large horizontal cylinder communicates on each side of its forward end, on the level of its horizontal diameter, with the two ends of the upper horizontal cast iron box of 10 inches square cross section and 9 feet 2¼ inches extreme length, by means of curved pipes 9 inches in diameter, through which the cylinder receives the steam generated on the tube surfaces, and any water that may come with it.

At the bottom of the back end of the large horizontal cylinder a pipe of 10 inches diameter and 12 inches length communicates with the centre of a horizontal pipe of 8 inches diameter, lying upon the top of the back wall of the boiler. This horizontal pipe has a length equal to the breadth of the boiler, and from each extremity a vertical pipe of 8 inches diameter descends to the corresponding extremities of the lower horizontal cast iron box of 10 inches square cross section and 9 feet 2¼ inches extreme length, thus completing the circulation of the water.

In order that the gases of combustion may pass over the entire tube surface, instead of taking a straight course from the grate to the chimney outlet, two diaphragm plates of wrought iron are introduced horizontally between the tubes, one above the other, in such manner as to equally divide the tubes. Both diaphragms extend entirely across the boiler, with one end touching either the front or back wall of the boiler, and leaving between the other or free end and the front or back wall, as the case might be, a sufficient space for the passage of the gases. The lower diaphragm leaves this space between its free end and the back wall of the boiler 2 feet 3 inches; the upper diaphragm leaves this space between its free end and the front wall of the boiler 1 foot 5 inches; so that the gases, after passing over the lower four horizontal rows of tubes in a direction from front to back, returns from back to front over the next four horizontal rows, and, finally, takes their original direction from front to back over the remaining four rows.

From the foregoing description of the boiler will be seen that unusual precautions were taken to keep the current of the gases of combustion thoroughly broken up and mixed, and to compel it to pass over the whole of the heating surface: the zig-zagging of the tubes, their position in the current which had to pass over them in a direction at right angles to their length, as well as in the direction of their

length, and the deflections produced by the diaphragms, causing the whole of the gases to pass in succession over only one-third of the tubes at a time, must have accomplished very completely the purpose.

The following are the principal dimensions and proportions of the boiler:

Length over all, including masonry,	13 feet 8 inches.
Breadth over all, including masonry,	9 feet 2 inches.
Height from bottom of ashpit to top of large horizontal cylinder,	15 feet 4 inches.
Breadth of grate,	6·168 feet.
Length of grate,	6·562 feet.
Grate surface,	40·4744 sq. ft.
Number of tubes at sides of furnace,	36.
Exterior diameter of tubes at sides of furnace,	5¾ inches.
Interior diameter of tubes at sides of furnace,	5½ inches.
Length of 12 of the tubes at the sides of the furnace,	7 feet 10½ inches.
Length of the remaining 24 tubes at the sides of the furnace,	9 feet 6 inches.
Number of tubes immediately over the grate,	144.
Exterior diameter of tubes immediately over the grate,	4¾ inches.
Interior diameter of tubes immediately over the grate,	4½ inches.
Length of the tubes immediately over the grate,	9 feet 6 inches.
Area of heating surface in tubes at side of furnace, calculated for half their inner circumference,	232·1821 sq. ft.
Area of heating surface in tubes at sides of furnace, calculated for half their outer circumference,	242·7369 sq. ft.
Area of heating surface in tubes immediately over grate, calculated for their inner circumference,	1611·6408 sq. ft.
Area of heating surface in tubes immediately over grate, calculated for their outer circumference,	1701·1764 sq. ft.
Area of all other heating surface,	44·0000 sq. ft.
Aggregate area of heating surface, calculated for inner circumference of the tubes,	1887·8229 sq. ft.
Aggregate area of heating surface, calculated for outer circumference of the tubes,	1987·9133 sq. ft.
Aggregate cross area between tubes horizontally,	9·2962 sq. ft.

Cross area between lower diaphragm and back wall of boiler,	2·2017 sq. ft.
Cross area between upper diaphragm and front wall of boiler,	1·3863 sq. ft.
Length traversed by the gases of combustion from centre of furnace to chimney outlet,	22 feet.
Exterior radiating surface of the cast iron boxes forming the front and back walls of the boiler,	269 square feet.
Water-room,	226·1 cub. feet.
Steam-room,	102·5 cub. feet.
Square feet of heating surface per square foot of grate surface, calculated for inner circumference of tubes,	46·6424.
Square feet of heating surface per square foot of grate surface, calculated for outer circumference of tubes,	49·1153.
Square feet of grate surface per square foot of opening for draught at lower diaphragm,	18·3832.
Square feet of grate surface per square foot of opening for draught at upper diaphragm,	29·1960.

Coal.

The coal consumed during the experiments with this boiler was semi-bituminous, from the mines of Monceau-Fontaine. It was an excellent steam-coal, and before being used had its dust separated by screening.

Analyses were made of two specimens, with closely agreeing results, of which the following are the mean:

Composition of the Crude Coal.

Hygrometric moisture,	2·80
Carbon,	78·57
Hydrogen,	3·85
Oxygen,	3·49
Nitrogen,	0·87
Sulphur,	0·42
Ash,	10·00
	100·00

Composition exclusive of Hygrometric Moisture and Ash.

Carbon,	90·10
Hydrogen,	4·42
Oxygen,	4·00
Nitrogen,	1·00
Sulphur,	0·48
	100·00

By Distillation in a Retort.

Volatile matters,	13·6
Coke,	86·4
	100·0

Manner of Making the Experiments.

The experiments occupied five working days, four of which were consecutive; the time in each day being 11 hours 11 minutes, 11 hours 5 minutes, 11 hours 40 minutes, 11 hours 44 minutes and 11 hours 30 minutes; making an aggregate of 57 hours 10 minutes. During these days the steam from the boiler was used in driving a steam-engine.

At the commencement of each day the boiler was kept for two hours with regular fire in the furnace and under the regular working steam pressure, in order that all parts might attain the temperature due to that pressure before beginning the experiment, the working pressure varying but a mere trifle for the different days.

At the expiration of the two hours the fire was wholly withdrawn from the furnace and a new fire kindled with a small quantity of wood, which was weighed, and its equivalent weight in coal added to the weight of coal consumed during the day. At the end of the day the fire was burned completely out, the water level and steam-pressure in the boiler being left the same as at the commencement.

The boiler was nearly new and perfectly clean. The tubes, as far as accessible, were swept of soot each morning before commencing an experiment, and again in the middle of the day.

The feed-pump supplied no other boiler, and at the commencement of the experiments all the connections with other boilers were broken, so that the experimental boiler was completely isolated. Before commencing the experiments the boiler was carefully tested under pressure for leaks, and found perfectly tight.

The feed-water was the water of condensation of the exhaust steam from the engine, increased by the quantity of fresh water required to make good the wastage. The steam produced in the boiler after being used in the engine was exhausted into a surface condenser, and thence the resulting water of condensation was delivered for measurement into a rectangular tank containing 6·71 cubic feet, from which it was again pumped into the boiler. The amount thus collected was found, by careful measurement during the five days, to be 7 per thousand less than the total quantity required to feed the boiler, which 7 per thousand was added in fresh water and is included in the vaporization given in the following table. This difference was due to spontaneous vaporization of the hot feed-water in the measuring tank, the temperature averaging 117 degrees Fahrenheit, and to losses at the safety-valve.

The coal was weighed every hour. The boiler pressure and the temperature of the feed-water were noted every half-hour. The fires were skillfully managed by an experienced fireman, and could not during any working day have needed much cleaning.

The most careful and varied observations failed to discover that any water was "primed" over from the boiler or entrained by the steam, the latter, in response to all tests, showing perfectly dry.

The maximum rate of combustion that could be sustained was $13\frac{1}{2}$ pounds of crude coal per hour per square foot of grate; the mean rate during the experiments was 9 pounds, so that the experimental rate was two-thirds of the maximum. As the chimney was in common for other boilers and purposes, the maximum rate of combustion is not due to the temperature of the gases discharged into it from the experimental boiler alone.

During the experiments the rate of combustion was considerably varied within the above limit for the maximum, but without certain effect upon the economic vaporization of the water, the difference in that result being but slight, not following any law, and having about the irregularity to be expected from unavoidable errors of observation and differences of condition which could neither be known nor allowed for if known. Consequently, the mean of the entire five days' experimenting are given in the following table, as being more accurate than the results from each day taken separately: the longer the time and the greater the number of observations the more reliable becomes the final result.

During the experiments the exterior surfaces of the cast iron boxes forming the front and back walls of the boiler above the top of the furnace were in contact with the external air and without protection from radiating heat. The temperature of the water within these boxes was 291 degrees Fahrenheit, and the surface thus exposed was 269 square feet. The joints between the boxes not being tight, considerable leakages of air must have there taken place into the gases of combustion, as well as through the walls of brick masonry.

Attempts to ascertain the temperature and composition of the gases of combustion when leaving the boiler were made, but, owing to the excessive inleakages of air and other causes, nothing reliable could be obtained in these respects.

In the following table will be found the data and mean results of the experiments for the five days aggregated. In reducing the weight of water vaporized to standard conditions, due allowance has been made for its variation in specific heat at different temperatures, and for the difference in the total heat of steam at different pressures.

Table containing the Data and Results of the Experiments made on the 26th, 27th, 28th and 29th of June, and on the 4th of July, 1878, by Mr. Vincotte with the Tubulous Boiler belonging to Mr. Demeuyer, at Willebroek, Belgium, to ascertain the Economic Vaporization of Water by Semi-Bituminous Coal.

TOTAL QUANTITIES.	Aggregate duration of experiments, in hours and minutes,	57h 10
	Aggregate number of pounds of crude coal consumed,	3070
	Aggregate number of pounds of refuse from the coal, in clinker, ash, etc.,	396
	Aggregate number of pounds of combustible or gasifiable portion of the crude coal consumed,	1790
	Per centum of the crude coal in refuse of clinker, ash, etc.,	14.29
	Aggregate number of cubic feet of feed water vaporized, measured in tank,	2815.000
	Aggregate number of pounds of feed water vaporized from its temperature in the tank,	17567.850
TEMPERATURES AND PRESSURES.	Mean temperature of the feed water, in degrees Fahrenheit,	117
	Mean pressure of steam in boiler, in pounds per square inch, above atmosphere,	40

Rate of Combustion.	Number of pounds of crude coal consumed per hour,	363·2711
	Number of pounds of combustible consumed per hour,	311·3703
	Number of pounds of crude coal consumed per hour per square foot of grate,	8·9753
	Number of pounds of combustible consumed per hour per square foot of grate,	7·6930
	Fraction of a pound of crude coal consumed per hour per square foot of heating surface, calculated for the inner circumference of the tubes,	0·1924
	Fraction of a pound of crude coal consumed per hour per square foot of heating surface, calculated for the outer circumference of the tubes,	0·1827
	Fraction of a pound of combustible consumed per hour per square foot of heating surface, calculated for the inner circumference of the tubes,	0·1649
	Fraction of a pound of combustible consumed per hour per square foot of heating surface, calculated for the outer circumference of the tubes,	0·1569
Vaporization. Absolute.	Number of pounds of water that would have been vaporized had it been supplied at the temperature of 100 degrees Fahrenheit and vaporized under the standard atmospheric pressure,	174777·5523
	Number of pounds of water that would have been vaporized had it been supplied at the temperature of 212 degrees Fahrenheit and vaporized under the standard atmospheric pressure,	195198·6723
Vaporization. Economic.	Pounds of water vaporized from 100° Fahrenheit by one pound of crude coal,	8·4161
	Pounds of water vaporized from 100° Fahrenheit by one pound of combustible,	9·8189
	Pounds of water vaporized from 212° Fahrenheit by one pound of crude coal,	9·3995
	Pounds of water vaporized from 212° Fahrenheit by one pound of combustible,	10·9662

Remarks.

The economic vaporization given by marine boilers of the water-tube system, consuming good steam-coal at the same rate per square foot of heating surface as in the case of the boiler experimented with, is, according to numerous experiments made in the Navy, 13 pounds of water vaporized from the temperature of 212 degrees Fahrenheit, under the standard atmospheric pressure, by one pound of the combustible portion of the coal. But in the boiler experimented with only 11 pounds of water were vaporized under these conditions,

or it was economically inferior to the marine boiler by about $\left(\frac{13-11}{13} \frac{100}{=}\right)$ 15½ per centum. This lessened economic efficiency was undoubtedly caused by the leakage of air through the joints of the cast iron boxes forming the front and back walls of the boiler above the furnace, and through the other walls of brick masonry, into the gases of combustion passing over the heating surfaces.

The air thus leaked in carries with it to the chimney the quantity of heat required to raise its temperature from that of the external atmosphere to the temperature of the gases leaving the boiler. This, however, does not include the prejudicial effect on the economic vaporization caused by the degradation of the temperature of the gases of combustion consequent on the mingling with them of the inleaked colder air; for only the excess of the temperature of the mingled air and gases over that of the boiler-water can be applied vaporifically. As an extreme example, suppose the quantity of cold inleaked air to be so great as to make the temperature of the mingled gases and air that of the water in the boiler, then, although the same quantity of heat would pass over the heating surface as before, yet none of it could be applied to the production of steam, and the whole of the fuel consumed would be absolutely lost in that respect, all the heat generated by its combustion passing into the chimney.

The mingling of cold air with the gases of combustion, by reducing the chimney temperature, reduces the force of the draught of the boiler, so that less fuel is consumed in equal times, and the draught is likewise made additionally sluggish by the greater quantity of gaseous matter to be passed in equal times through the chimney; and the economic vaporization is also decreased because the rapidity with which heat passes from the hot gases to the water in the boiler is in the proportion of the difference of the temperatures of the water and gases. In every point of view the inleakage of cold air is highly disadvantageous to both the economic and the potential vaporization by a boiler, and should be carefully guarded against. The waste of fuel in land boilers set in brick masonry, due to this cause, is enormous and the consequence of pure ignorance.

The water in the boiler was analyzed each day, and the following was its mean composition by weight:

Water,	999·2015
Lime,	0·1429
Magnesia,	0·0054
Alkalies,	0·1444
Chlorine,	0·2149
Sulphuric acid,	0·2865
Carbonic acid,	0·0044
	1000·0000

This water was alkaline, but its alkalinity, which was due to the magnesia and, probably, lime resulting from the decomposition of the carbonates of these two bases, was lost by the calcination of the solid matters dissolved in it. These two oxides are found in the solid residue in presence of organic matter which during the circulation furnished them with carbonic acid.

An examination of the water of condensation drawn from the surface condenser showed it to be strongly acid and containing iron, while the water in the boiler from which it was distilled was alkaline and free of iron. The acid was found to be carbonic acid; the iron was in the state of carbonate of iron, and came from the iron tubes of the surface condenser. The action on these tubes was so rapid that the clear water of condensation after standing one night in the condenser was discolored and ochrous in the morning. This water, after the removal of the acid and iron, was absolutely pure. If the water was allowed to stand, the acid left it spontaneously, and at the end of about fifteen days was nearly all gone.

The writer has observed the same destructive action of the water of condensation on the cast iron shell of the surface condensers of marine engines, due to the gaseous acids brought over with the steam from the boiler and dissolved anew in that water. It is quite an error to suppose the water of condensation obtained from a surface condenser in ordinary use is pure distilled water: it is both acid and ochrous.

That no water was "primed" over, or entrained by the steam during the experiments, was due to the large capacity of the steam-drums and to their height above the water level, as other boilers of the same type, not so well provided in these particulars, are found to prime considerably, though such steam-drums do not belong to the theory of this kind of boilers.

One of the great advantages of a boiler like the one experimented

with, in which the water is contained in small tubes, is its less probability of explosion, and the less destructive effects should an explosion happen, than in the case of boilers with either cylindrical shells or rectangular shells stayed at intervals. The less probability of explosion results from the fact that the small tube is stronger to resist a given internal pressure than a large cylinder or stayed flat surface. The less destructive effects of an explosion, should one occur, results from the fact that the boiler composed of small tubes contains less water for a given heating surface than those whose shells are cylindrical or rectangular.

The explosion of a boiler is not instantaneous; it is progressive. Its more or less violence depends on the force accumulated in the boiler, and on the duration of the explosion itself. The force accumulated depends almost exclusively on the quantity and temperature of the water. Suppose, for example, that a cubic foot of water heated in a boiler to the temperature corresponding with a pressure of 60 pounds per square inch above the atmosphere, should be suddenly discharged into the air, it would produce about 185 cubic feet of steam of atmospheric pressure. Let the volume of steam in the steam-room of a boiler under the supposed pressure be the greatest given in practice, it will bear but a feeble proportion when expanded to the atmospheric pressure to the volume which will be produced from the water in that boiler, and it will contribute to the destructive effects of the explosion only in that proportion. Practically, the distance to which the destructive effects of a boiler explosion extends, and the intensity of the destruction, increase in proportion to the quantity of water contained in the boiler and to the temperature of that water.

When one or more plates of a boiler are ruptured by the pressure, a considerable fraction of its contained water passes into steam under the lessened pressure thus produced, and this transformation takes place suddenly on all the particles of the water, in measure and to the extent as they emerge into the gradually lessening pressure; so that it depends on the size and situation of the first rupture relatively to the objects in front, whether the steam they thus encounter is sufficient to destroy them. The explosion of a boiler containing but little water may sometimes kill those who are in close proximity, but the destructive effects are small and limited to the near locality. When, on the contrary, the quantity of water in the boiler is large, the surrounding

objects and the fragments of the boiler itself are violently hurled by the explosion and its destructive effects extended into remote places.

From the foregoing considerations it would seem that, in function of safety, boilers should be composed of separate similar parts, the more numerous the better, other things equal, and that each part should contain the minimum of water, conditions which are well fulfilled in the boiler experimented with, whose every vertical row of connected tubes may be considered as a complete and separate system; so that in the event of an explosion there would be but little water to cause destruction, and that the water in the different parts would flow slowly and in succession towards the fracture for projection into the air, thus rendering the discharge as prolonged as possible, and the effect, consequently, a minimum in intensity.

These conditions, unfortunately, have but a limited application. The free circulation of the water in the restricted separate parts is much impeded, and the small quantity of water itself becomes a serious defect in view of the difficulty of maintaining with it a uniform pressure of steam. The less the mass of water the less constant is the pressure.

When the fires are urged beyond a certain point the steam is so rapidly formed in the tubes, proportionally to the vent for its escape, that notwithstanding the considerable inclination given to them, the water is driven out at both ends, to return again, intermittingly, upon the metal overheated in its intervals of absence. As the tubes lie directly over the grate, the heat comes equally upon nearly the whole length of the four lower rows, so that there is nothing but their inclination to produce a circulation of water. These lower rows are impinged on by the gases of combustion at their maximum temperature as they first rise from the incandescent coal whose radiant heats also acts at the same time equally upon their whole length, so that the generation of steam must be enormously rapid there, while the only means of producing a circulation or water current through these tubes is the difference in the heads of water at their two ends.

This slight provision for establishing a circulation is neutralized in sea-going steamers by their pitching, rolling or permanent heeling over under sail, so that this type of boiler is absolutely precluded from marine use on that account. Under favorable conditions it can be employed for land service, but if attempted to be used at sea will speedily be itself destroyed, and probably cause grave accidents.

The slipping on each other of the cast iron boxes at the front and back of the boiler, into which the tubes are secured by pairs, makes a provision for any unequal expansion and contraction they may undergo from differences of temperature. But, as these free joints to move are also free to admit the cold atmospheric air, the entire front and back of the boiler should be enclosed by air-tight doors, which, though adding to the cost of constructing the boiler, would materially lessen the weight of coal consumed to produce a given quantity of steam in a given time.

The heating surface per unit of area in boilers of this description, as compared with that of boilers of the usual construction, is very inefficient. Less water, other things equal, will be vaporized in them per square foot of surface, because all the stem generated in the lower tubes has to force its way, successively, through the upper tubes, alternately, from end to end, displacing to that extent the water in the latter and thus preventing its contact with the metal. In other words, less water is in contact with each unit of area of heating surface in boilers of this kind than in boilers of the ordinary construction. Hence, to obtain an equal economic vaporization, a much greater proportion of heating surface to grate surface must be given, or a much less rate of combustion adopted. In the experimental boiler there were 49·1153 square feet of heating surface to one square foot of grate surface, a proportion approaching what is given in many locomotives with their enormous rate of combustion. A well designed ordinary boiler with half this proportion of heating to grate surface, and the experimental rate of combustion, would have given equal economic and potential results. Real improvement in engineering consists in accomplishing equal effects with less expenditure of material and labor.

Digestive Ferments in Vegetables.—M. Bouchard was led to believe, by his discovery of papaine, the digestive ferment of the *Carica papaya*, that there might be a general carnivorous property in the latex of many other vegetables. Some special careful investigations confirmed him in this belief, and his experiments with the milky juice of the common fig tree showed that it contained powerful digestive properties. He proposes to continue his researches in order to discover the nature of the new principle of vegetable pepsin.—*Comptes Rendus.* C.

THE WEAKENING OF STEAM BOILERS BY CUTTING HOLES IN THE SHELL FOR DOMES AND NECKS.

By W. Barnet Le Van.

(Continued from page 323.)

The association above referred to at the time the "French" boilers were offered for their guarantee, had under consideration several instances of explosion, which had been attributed by their chief engineer to the employment of such necks, and to large openings not sufficiently strengthened, led the committee to the determination to try the matter fully. Indeed, so completely were they alive to the weakness resulting from the large holes at the base of steam domes, and the presence of domes at all, that they had for years urged members when laying down new boilers, *to dispense with domes altogether.*

It was, therefore, arranged that a proper boiler should be constructed, of the diameter adopted in daily practice, and of the usual thickness of plates, with actual manhole, mouthpieces, etc., such as are common, so that the ultimate test should be decisive.

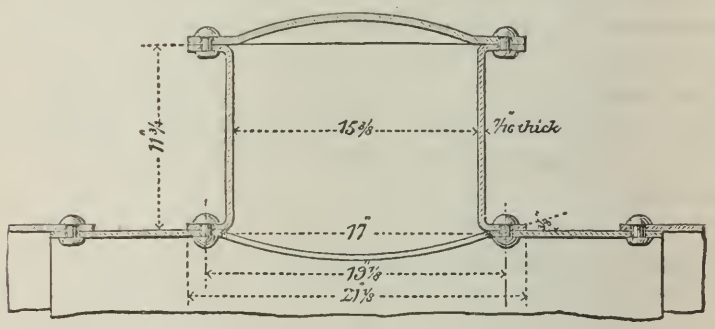


Fig. 6.

With this object then in view, they had a boiler constructed 21 feet long by 7 feet in diameter inside the inner plate of shell; with two furnace tubes 2 feet 9 inches inside diameter with flanged seams, each ring being welded up solid so that there would be no rivets or lap joint in the flue. The shell plates were $\frac{7}{16}$ inch thick, the ends

welded up solid were ½ inch thick, and the furnace tubes of ⅜ inch plate, the material throughout being of best Sneedshill iron. All longitudinal joints were double-riveted, and circumferential ones single-riveted. The holes were punched.

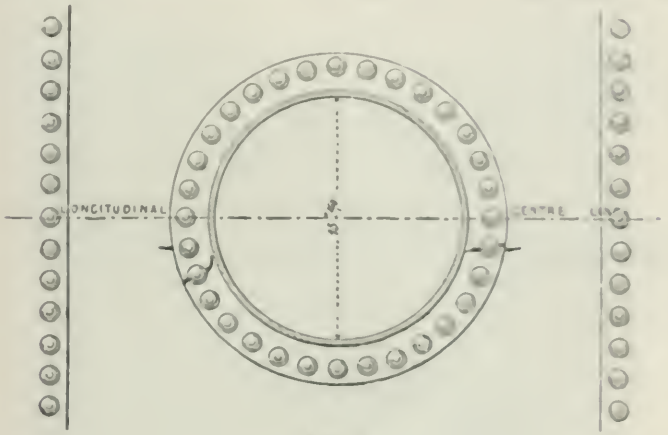


Fig. 7.

In the first experiment that was made the boiler was complete in all its details. The manhole mouthpiece was of wrought iron, such as recommended by the association. The cast-iron pipe or seating for the blow-off elbow pipe to attach to was also as is usual, while the gusset stays and longitudinal stays were the full complement provided for such a boiler for 75 pounds working pressure. The front end manhole casting was placed on the inside of the front plate and furnished with internal door and usual cross bar fixings. The wrought-iron neck on the top of boiler and on the central plate was the special object of this first experiment, and it is clearly shown in Fig. 6, in which all the dimensions are fully given. Fig. 7 is a sectional plan of this neck, and Fig. 8 shows, as does also Fig. 7, the lines where fracture ultimately took place. Before pressing the boiler up to the bursting point, careful records were taken as to the behavior of the boiler at all points, as the pressure gradually rose. The flat ends were carefully gauged to ascertain at what pressure and to what extent they gave way, and if any permanent "set" remained on withdrawal of pressure.

The furnace flues were carefully gauged; the length of the boiler shell measured by rods fixed at one end and free at the other end,

and having pointers at several places, and the circumference was also measured by two encircling steel bands passed round the boiler and weighted at each end, so that by horizontal lines drawn across them the least enlargement could be rendered clearly visible; some of these measuring preparations are shown in Fig. 9.

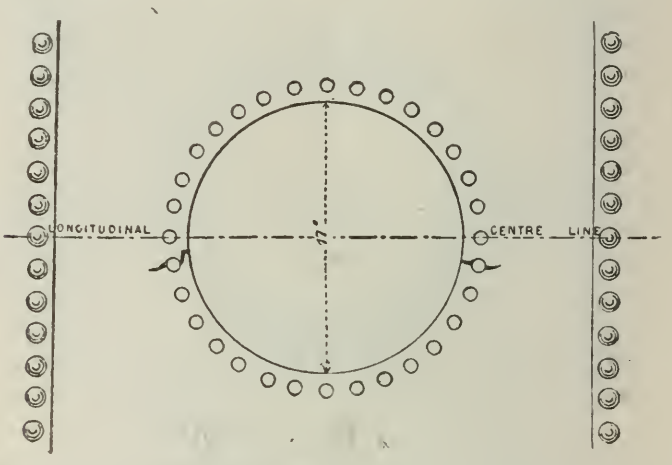


Fig. 8.

Up to the pressure at which the wrought-iron neck (Fig. 6) gave way, viz., at 250 pounds on the square inch, there was no movement of the ends beyond a slight permanent "set," which has remained the same throughout the whole of the test, even after the removal of the two longitudinal stays, by which fact it is clearly shown that the arrangement of gusset stays here used is sufficient to secure the ends up to and beyond the limit of the strength of the shell.

The first rupture took place at the base of the 14 inch neck, and is shown in Figs. 7 and 8. Of course these fractures are, in themselves, as here shown, only the commencement of the work of destruction, but it is self-evident to any one understanding the subject that had the volume of water which was supplied at the pressure of 250 pounds been greater, the rent would have extended instantly, and had steam pressure been the agent used instead of water then complete destruction must have followed, by the development of rents in various directions, and with the usual accompaniments of loud report, damage to property, and probably loss of human life.

The boiler having been repaired by the attachment of a strong circu-

lar plate where the neck had been placed, as may be seen in Fig. 9 on the top of the boiler, was furnished with a cast-iron manhole mouthpiece of the usual form. This casting was circular and was 16½ inches inside diameter, and is shown in Fig. 10, and may here be compared with the wrought-iron manhole mouthpiece, Fig. 11, which is 17 inches internal diameter, and upon a hole in boiler shell 18½ inches diameter. It will be seen that the cast-iron manway is 16½ inches diameter inside, but requires a larger hole in boiler shell, viz., 20 inches diameter, to bring the edge of the plate to its proper distance from the centers of the rivets. The casting, which was of strong and substantial pattern and quite sound throughout, gave way at a pressure of 200 pounds per square inch, a large part of it flying off with considerable force, and so much more violent was the rupture than had been the case in the instance of the wrought-iron neck at 250 pounds that the shell plate was torn completely through on each side of the manhole, the rents being longitudinal until diverted by the resistance offered by the two ring seams through which they forced their way, and thence they began to pass circumferentially through the neighboring plates. Here again are clear lines of commencing rents whose ultimate development it is self-evident must have been utter destruction. The fractured portions of this casting are shown in Fig. 9, as is also the first wrought-iron neck with its fractured flange.

At the next or third experiment a steam dome 3 feet in diameter was applied, only a small portion of the boiler shell having been cut away, but the strain at the base of the dome was such that violent leakage ensued, so that no more than 235 pounds pressure could be maintained with the pumping power at command. A second trial was made with this dome, when it had been re-riveted with stouter rivet heads, suited to resist more satisfactorily the strong upward strain that was produced by the internal pressure, and in this case rupture was produced by the tearing of the bottom flange of the dome on the centre line of the boiler at a pressure of 200 pounds. Up to this period the gauging of the flues and ends had been carefully noted, but no signs of distress were discovered, nor had any strain of the flat ends taken place.

The fifth test was made to ascertain the value of a single-riveted joint as compared with a double-riveted one, and it was found that at 250 pounds the leakage at the single-riveted joint was so great that

the pumps were overpowered, and no increase of pressure could be obtained; the double-riveted joint remained quite tight.

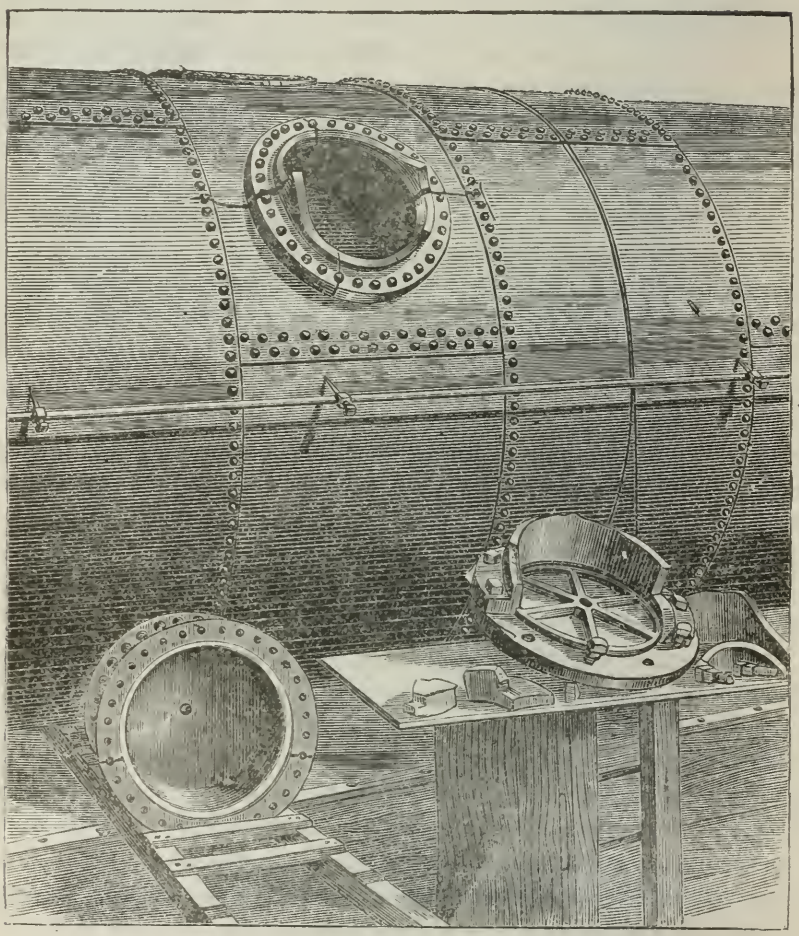


Fig. 9.

The sixth test was to ascertain the strength of an ordinary unguarded manhole with internal door and cross bars, such as have been in time past so very generally used, and are indeed but too often met with even now. The oval hole cut in the shell measured 17 inches by 13 inches, and in this case it must be remembered that the whole apparatus was *new* and of first-rate construction, so far as the imperfect system of such a manhole and cover could be good. The inner cover

lapped well to the boiler shell, and the joint having ample surface, was made with new sheet india-rubber. The cross-bars were of the proper length, so that their feet rested upon the shell plate, not beyond the limit of the cover below, but immediately over the lap, and thus the chances of the door were far above the average rate of strength. There was, of course, no loss of strength from repeated renewal of such a joint or from corrosion, but the door threw out, as is shown in Fig. 12, at a pressure of 200 pounds per square inch, a longitudinal rent starting from one end of the manhole and running across the plate, and then extending some distance along the ring seam of rivets, and fracturing the next plate through a rivet hole.

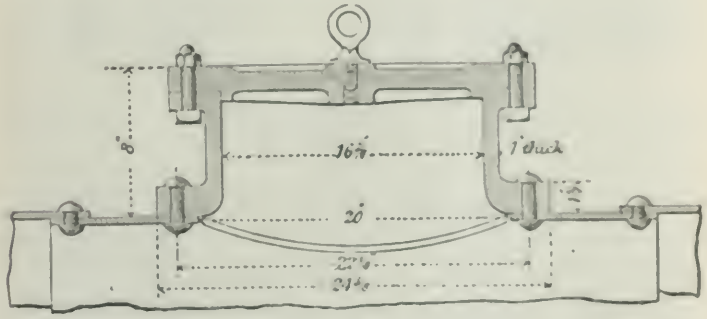


Fig. 10.

Test number seven was a repetition of number five, to try if a rent instead of a simple leakage could be produced with a greater amount of pumping power, the idea having arisen that perhaps a single-riveted joint might be taken as a sort of safety valve through which sufficient leakage and relief from pressure might ensue in case of over-pressure, and thus lead to the prevention of actual explosion. Such a theory, if not disproved, might have a very dangerous tendency, and the necessity of complete assurance was felt to be absolute.

With augmented pumping power, this question was set at rest by the complete fracture of a single riveted seam (machine work) at 275 pound pressure, when the rent extended the whole width of the plate, and passed into each side ring plate, the rent being about 5 feet 6 inches long, and such as would most inevitably have caused the whole shell to open out with most destructive results.

Double-riveted work executed by hand was then compared with machine work, with a result similar to the last, in so far as this rent

was very decisive and complete, the hand-worked seam giving way at 300 pounds pressure, while the machine work remained good.

Previously to this there had been some intervening test regarding the stays, after which the longitudinal stay bolts were removed altogether, and the boiler was tested without them from that time to the end of the trials, so far as they have been carried, and no yielding of the ends has yet occurred.

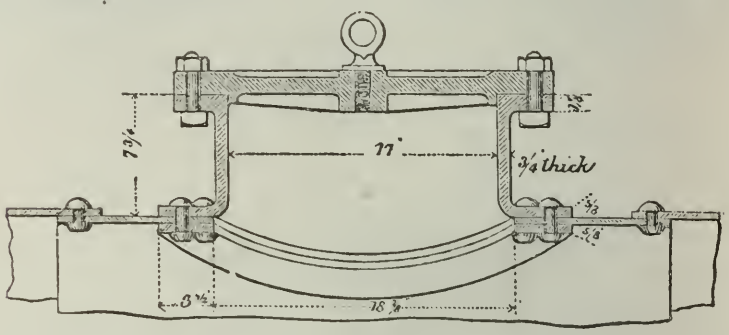


Fig. 11.

Before reaching the highest resistance of which the boiler was reckoned capable, another illustration was afforded as to the risk of placing reliance on cast-iron seatings for fittings to steam boilers. When the boiler had been once again restored with all joints double-riveted by machine, and everything as good as could be, considering the many tests the boiler had gone through, a somewhat unexpected fracture took place in the only remaining external cast-iron seating, viz., that below the boiler at the front end furnished for attaching the blow-off elbow pipe to. At 300 pounds pressure this casting gave way, tearing the shell plate longitudinally, as had been the case in all other such fractures, and straining the lower part of the front plate together with the front internal manhole mouthpiece inwards, and tearing the external angle-iron at the lower part of the boiler.

This had to be repaired, and thus after it had by successive trials been shown that one cast-iron part after another must be discarded, the final burst was attempted, and successfully carried out on the 11th instant, when at 310 pounds pressure a clear longitudinal rent was caused in the central ring of plates, and at the bottom of the boiler, just at the very spot that by all calculation should have been the weakest. Possibly, had the whole boiler been quite new when this last test was applied, and the iron not been subjected to repeated strains closely approaching its limit of strength, the pressure would have reached 320

pounds, or the ultimate calculated strength of the double-riveted joint. Be this as it may, it has now been demonstrated that this form of Lancashire boiler, fairly made, and of good material, is reliable to the extent that calculation would lead one to expect. These experiments were witnessed from time to time by many gentlemen who take a great interest in such matters and stand foremost amongst the engineers

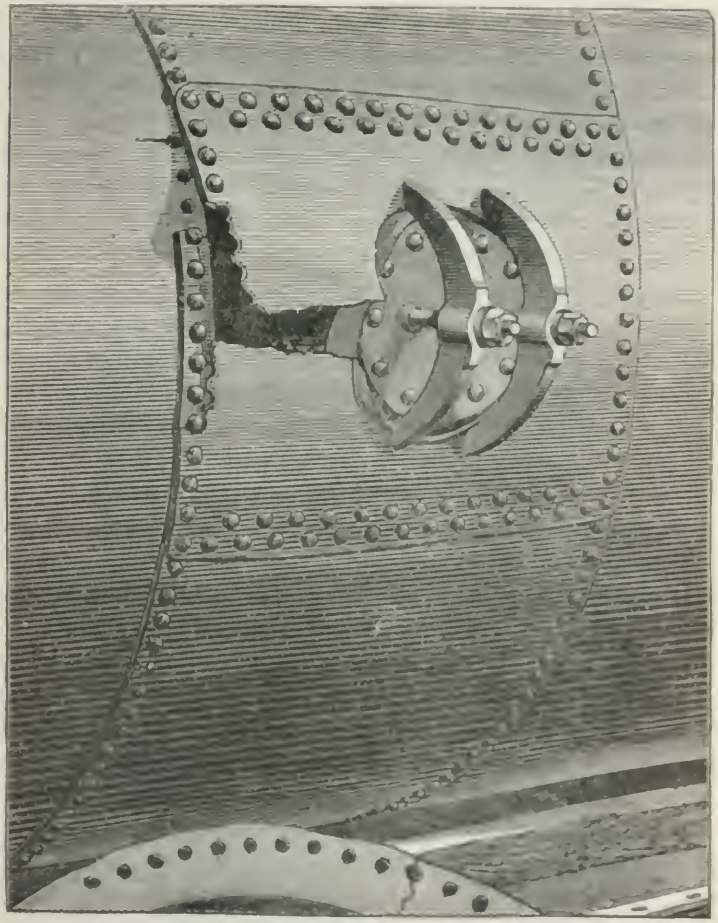


Fig. 12.

of England, amongst whom may be mentioned Mr. J. Ramsbottom, Mr. Turnbull, Mr. Inglis, Mr. Scarlett, Mr. Thomas Traill, Chief Inspector of the Board of Trade, also one of the staff of engineers of *Engineering*. The boiler was made by Mr. Thomas Beeley, of Hyde Junction Iron Works, near Manchester, under the direction of Mr. Lavington E. Fletcher, the Chief Engineer to the Steam Users' Association.

NEW ELECTRIC MOTOR.

By William Woodnutt Griscom.

Paper read before the Franklin Institute Nov. 17th, 1880.

An electric motor, as the name indicates, is an engine for converting electricity into mechanical force. This is done most efficiently through the medium of electro-magnetism, and the honor of inaugurating the movement which has led to the utilization of this force as a motive power belongs to our own Professor Henry. His first paper on this subject appeared in 1831. In the following year Salvatore dal Negro constructed his motor and described it in detail. The first electric motors were rude machines, about as efficient as Hero's steam engine, but it hardly took the world more years to perfect the one than it required centuries to complete the other. Dal Negro's motor consisted of a fixed electro-magnet, which, by suitable interruptions of the electric current, alternately attracted and released a lever by which the mechanism was driven.

In 1835 Prof. Jacobi, of St. Petersburg, constructed an electric engine at the expense of the Czar Nicholas, with which, after four years of further experiment, he was able to drive a twelve-oared boat against the swift current of the Neva at the rate of three miles an hour. His enormous battery consisted of sixty-four cells, containing twenty square feet of platinum.

This was in all respects an apparent failure, and the philosopher was thoroughly disheartened while standing unwittingly on the threshold of a brilliant success. In the first place, he attempted the impossible in trying to get a great power economically from any battery, and in the second place no powerful battery had yet been invented. But his engine was an excellent one, and the subsequent inventors failed to equal it until Gramme, of Paris, discovered that one of his own dynamo-electric generators would act in the reverse direction as an admirable motor.

The interval between 1839, when Jacobi's motor was abandoned, and 1870, when Gramme's machines came into notice, was occupied by a large number of inventors, who brought to their work a world of ingenuity, and all the learning of all the sciences save one, but that

one was the only key to success—*electro-magnetic induction*. In the meanwhile Mr. Joule, himself a former seeker after this nineteenth century philosopher's stone, dashed the hopes of his co-inventors by his demonstration of the Conservation of Energy. This magnificent work, the grandest perhaps in the history of science, was immediately made the basis of a series of experiments, which it would be out of place to detail here. Suffice that Mr. Joule proved to the satisfaction of all scientific minds that the mechanical energy of the electrical current, produced by the consumption of one pound of zinc in a Daniell's cell, is equal to 1,106,160 pounds raised to the height of one foot; in a Grove's cell, which has 1½ times the electro-motive force of Daniell's, to 1,843,600 pounds raised to the height of one foot, or, in the sulpho-chromic acid battery now before you, which has double the electro-motive force of a Daniell's, 2,212,320 pounds raised to the height of one foot. Dr. Scoresby and Mr. Joule state their conclusions in the following sentence: "Upon the whole we feel ourselves justified in fixing the maximum available duty of an electro-magnetic engine, worked by a Daniell's battery, at 80 pounds, raised one foot high for each grain of zinc consumed." This is about half the theoretical duty. In a Grove battery the same proportion would give 144 pounds, and in the sulpho-chromic battery 160 pounds, raised one foot high for each grain of zinc consumed. This result was immediately compared with the duty of the best type of steam engine per grain of coal, and it was found that one grain of coal lifted 143 pounds one foot high. But zinc, at the most favorable computation, costs ten times as much as coal, and the force it yields is, therefore, as 143 is to $\frac{160}{10}$, or about nine times as costly.

The conclusion instantly drawn by the scientific world was that electricity produced by the consumption of zinc can never compete with steam, but it is the purpose of this paper to collect certain facts which will show that this conclusion is erroneous.

History is teeming with instances where noted scientific men declared that there was nothing attainable beyond their immediate vision, and proved with sarcastic argument and brilliant syllogism that further advance in certain directions was impossible. So it was with the steamship. An eminent scholar and mathematician, some fifty years ago, proved beyond the peradventure of a doubt that an ocean steamship was an absurd dream. His calculations showed that one could not be built large enough to carry her own coal across the Atlantic.

And so these gentlemen, having proved that electricity produced by zinc is nine times as costly a source of power as steam produced by coal, predict that electric motors can never usefully compete with steam engines. Now, man-power, according to the tables of a well-known English engineer, is one hundred times as costly as steam; nevertheless there are several circumstances in which we prefer men. It is certain that we would never employ men if we could get a steam engine to do the work more cheaply, and it is equally certain that we would not use electricity where steam was applicable. But steam is *not* applicable, for reasons which will be given later in detail, to work in which we require a small amount of power in constant readiness for action. In these cases—such as jewelers' lathes, dental engines and the various tools of small machine shops, which employ but a small force of men—we have never been able to find a source of power adapted to the work which, if not as cheap in proportion as large steam engines, should yet be more economical than human energy. The fact is that whereas, according to Joule, the best electric motors are nine times as costly as steam power, human energy is eleven times as costly as electricity. And, inasmuch as human energy, which is one hundred times as costly as steam, is frequently preferred to steam engines, *a fortiori* electricity will often be preferred to steam; and it will require no argument to show that the human energy thus saved from exhaustion in the exercise of brute force can be devoted to a higher use.

By way of illustration, the application of human energy to the sewing machine is not only a false economy, but has proved the cause of many new and painful diseases in female operators, which embitter their lives and affect the physique of their offspring. If any motor can be substituted for human energy in this field, there can be no greater or more convincing consideration offered to invite attention to it.

The sewing machine is in almost every house, and the seeds of these diseases are spread in every class of society. The remedy, as before mentioned, is a household motor, and it was natural to suggest a small steam engine for this purpose; but steam is unsuited to this end, because—

1st. It requires time and trouble to start it to work, and a busy housekeeper, who may only need, perhaps, to do five minutes of sewing, has no time to waste.

2d. It is always liable to explode, or to burn out the boiler, or get various portions of its complex mechanism out of order, so as to require an experienced engine driver to repair it.

3d. It emits an offensive odor of burnt or boiling oil, and vitiates the atmosphere with the products of combustion.

4th. It is really much more expensive than those steam engines from which our calculations were made. If gas is consumed for a household engine, the fuel amounts to from twelve to twenty-five feet of gas per hour, costing for a motor giving one thirty-third of a horse-power, as much as the fuel of a six or twelve horse-power steam engine.

This last consideration would not weigh with the actual sufferers of the acute forms of disease, but the other objections are serious, and apply to all heat-motors, such as gas, steam and caloric engines.

Other motors are before the public—the various hydraulic motors which require the special introduction of water-pipe and waste-pipe, and entail yearly visits from those friends of humanity, the plumber and the tax-collector. Then there is the spring motor, which you wind up every quarter of an hour or so, expending, of course, much more power in the winding than you get out of it in work, and which has an unhappy habit of bursting its bonds occasionally and venting its store of energy where it is least needed. Then there is the curious chair motor, whose mechanism is connected with the seat of the chair, and by various levers, cogs, cams and clutch to the sewing machine. The seat of the chair gradually sinks about three inches beneath the weight of the operator, driving the sewing machine the meanwhile. The operator then rises, the spring lifts the seat and the performance is renewed. A rapid speed can be attained by rising and sinking forty times per minute.

It is now fair to examine the theoretical and practical objections to electric motors, used with batteries. They may be divided into two classes—those which utilize the attraction only of an armature to an electro-magnet like the motor which drives the clock in the Lenox library up-stairs, and those which utilize the attraction and repulsion of two or more electro-magnets.

The former act by intermittent attraction only, and are wasteful of electric energy, because the residual magnetism, during the interruption of the current, retards the passage of the armature away from the pole which had just attracted it.

Those of the latter type, however, convert a portion of the retarding influence of the residual magnetism into a useful force. In fact, all dynamo-electric generators, when used as motors, convert all magnetic resistance to motion into a counter electro-motive force. At first glance it seems strange to consider a counter force as an economy, but in point of fact it retards the consumption of zinc in the battery and tends to depolarize the negative plate. It has been usual to regard this counter electro-motive force as increased resistance, but a simple experiment will show the error of this view, and will at the same time demonstrate that economical motors must also be efficient dynamo-electric machines in order to recover this force, which would otherwise be lost. A small motor of the type before you was held motionless while a sufficiently powerful current—let us say of four vebers per second—traversed its coils. A tangent galvanometer was in circuit, whose deflection was carefully observed. Then, without changing the connections, the motor was allowed to run at full speed, when the galvanometer indicated about one-fourth of the original amount of current. The electro-motive force of the battery was practically constant, and, therefore, according to the formula

$$\frac{\text{Electro-motive force}}{\text{Resistance}} = \text{Current}$$

the galvanometer should have indicated the same current as at first, unless the resistance had been changed or a counter electro-motive force produced. The speed of rotation was then diminished by a brake, and the needle immediately indicated a greater current. This is in direct conformity with the well-known law that the electro-motive force of a dynamo-electric machine varies with the speed of rotation, whereas the resistance of a coil is not affected by mere motion.

A still more striking proof that the "back-pull" of residual magnetism may be converted usefully into electricity is exemplified in a motor constructed more than a year ago by the writer on the same principle as this one, save that the field-coils are free and not connected with the battery. The current of the battery is sent through the armature, which revolves with considerable rapidity. If the free ends of the field-coils are now connected the speed is immensely increased, and if the ends are separated a spark appears. Of course there is some loss. The entire amount of energy wasted in retarding the armature is not recovered, but nevertheless the increase of power due to this one economy is very astonishing.

The little motor exhibited this evening is also an efficient dynamo-electric machine. The most essential advantage which it possesses over the older forms is in the field magnets. Their peculiar shape is such that all the magnetic lines of force, including those nearest the neutral line, are brought into the best possible position for effecting the revolution of the magnetic armature. I believe that the distinguished inventor, Mr. Ladd, of England, claims, in an article which appeared lately in one of the journals, to have discovered the great advantage possessed by the lines of force of a nearly circular magnet over those in the usual horse shoe form magnet, but he does not appear to have attempted to utilize the lines of force which fill the interior of a curved magnet from the neutral to the polar points. If a bar of soft iron is pivoted at one end, so as to move in a horizontal plane, and a semi-circular magnet is placed concentrically with the circle which the bar can describe, it is found that a given force is exerted upon the bar, at a much greater distance from the poles, when the latter is within the semicircle than when it is without. I believe that no field magnets of this principle have ever before been made, and herein is the secret of the power of this little motor, which weighs about 24 pounds, and which compares favorably with those of the old forms of fifteen times its weight. The inductive actions which are produced in these field magnets at each revolution of the armature are exceedingly complex, and I shall not trespass further on your attention, except to give a brief resumé of the practical defects of electric motors, and how they have been overcome in the investigation of which this motor is the result.

The great bugbear of those who have used electric motors has been the battery. It gave forth offensive and poisonous vapors; it required almost continual attention; it used concentrated acids, and it became rapidly exhausted whether it was used or not. It was the frequent cause of accidents to clothing, its cells were readily broken and the connections were constantly eaten away.

All these objections are now done away with. The present battery is inclosed in a strong watter-proof box, does not use concentrated acids, gives out no odor, does not exhaust itself, requires renewing only after the fluid is used up by actual work, will last months or years if left to itself and be in as good order as at the beginning. It requires absolutely no attention until the reservoir is exhausted by actual work, and it is ready without a moment's warning at all times and seasons.

It is calculated that the battery will suffice for the sewing of a small family for one year. A professional seamstress would exhaust it more rapidly, but always in proportion to the exact amount of work done. It will be shown that this form of battery places the speed of the motor under complete control without effort on the part of the operator.

The attention of mechanicians is invited to the fact that this form of motor, owing to the force being applied equally to both sides of the shaft at once, entails absolutely no wear on the journals except from the weight of the armature, which is very light, and the tension of the belt, which transmits the power. The length of bearing is four times the diameter of the shaft, and the design of the motor is such that no amount of wear can cause the poles of the armature and magnets to come in contact, which was a frequent source of annoyance in other motors. The motor is attached to the machine, and is of such dimensions as to be readily concealed from view if preferred. There is also a device for readily changing the tension of the belt.

The power of the motor is sufficient to sew leather, or as much tightly woven linen as can be put under the presser. With a sufficient battery power it can give any speed varying from twenty to two thousand stitches per minute in instant obedience to the will of the operator. A safe working speed for constant use is eight hundred to one thousand stitches per minute, which is considerably faster than is now attained by professional sewing women, while others seldom sew more than three hundred to four hundred stitches per minute.

[The principles embodied in the paper were illustrated by a small model weighing 2½ pounds attached to a sewing machine and a battery of six cells, each containing one plate of zinc four inches long and two inches wide. The machine did both light and heavy work, and the speed was under complete control. The battery was sensibly constant, showing no signs of polarization. The current was estimated at two vebers per second, and the force generated at 1000 ft. lbs.] N.

Vapor Tensions at High Temperatures.—Sajotschewsky finds that vapor tension, up to the critical point, is independent of the space occupied by the liquids, but above that temperature the curves, which previously coincided, separated from one another when the quantity of liquid in a given space was made to vary.—*Proc. Vienna Acad.* C

THE SAWYER ELECTRIC LIGHT.

A public exhibition of the Sawyer electric light was given at the Hall of the Franklin Institute on Tuesday evening, Nov. 9th, under the auspices of the company, at which Mr. W. P. Tatham was invited to preside. Mr. Sawyer, though present, was too unwell to address the audience and was obliged to leave before the close of the meeting. In his absence, Mr. Hatfley said that the lamps would have to speak for themselves, and showed how they could be turned up or down and regulated to any desired illuminating power by the turning of a switch. He said that Mr. Sawyer and the capitalists connected with him proposed to submit these lamps and dynamo machines to the Franklin Institute for tests as to illuminating power and cost of production, knowing that the Institute could not be bought or influenced in its judgment. He added that Mr. Sawyer was entirely willing to submit to the judgment of the scientific men connected with the Institute.

Description of the Light.

The Sawyer light is designed for household use, and is produced by the incandescence of a small pencil of carbon. It differs essentially from the voltaic arc lights, of great power, such as are exhibited on Chestnut street. The household lamp, which is the principal feature, has a pencil of carbon, about one-sixteenth of an inch in diameter and eight inches in length. This is continuously fed upward by means of a coil spring against a cylinder of carbon probably three-eighths of an inch in diameter. The current of electricity passes without interruption through the upper cylinder of carbon, then through the pencil for about three-eights of an inch, when it passes off into a cylindrical clamp of carbon and through the standards on which the whole apparatus is erected. The carbon pencil is enclosed in a glass shade probably ten inches in height and two and a half inches in diameter, which is sealed and charged with nitrogen. The carbon pencil is gradually consumed, hence the necessity for the spring which feeds it up continuously against the carbon cylinder. The current of electricity meets with such resistance in passing through the part of the pencil three-eighths of an inch in length that it raises it to a white heat, and this is the source of light. The lamps are said to cost from $4 to $6, but

can be manufactured in large numbers at much less cost. No electrical apparatus or clockwork is required to keep the carbons in position, a spring to maintain constant pressure being all that is needed. The larger sized lamps have carbons about one-eighth of an inch in diameter, and the light-giving part is from one to one and a quarter inches in length. The small lamps are reckoned at thirty-candle power, the large ones at 200 or 300, and the inventor claims that he can maintain two of the large lamps or five or six of the small ones per horse-power used in driving the dynamo-electric machine. It is said that the large lamps will run from one to three months without renewal of the carbons, and the small ones from three months to a year, the difference in time being due to the perfection attained in charging the smaller lamps with nitrogen. The cost of renewing the carbons and recharging with nitrogen will probably not exceed fifteen cents. The light of each lamp can be turned up or down at will with as much ease as the light given by a gas burner, resistance being introduced in place of the lamp the light of which is reduced.

Attached to the whole system of lighting is a water regulator, designed to regulate the current in proportion to the use made of it, so that one light or a dozen, or more, in the circuit can be lighted or turned out without affecting the others. The power for doing this is obtained by water pressure, say from a hydrant, a portion of the electric current being used simply to open or close a valve regulating the use of this power. The regulator was out of order, but is intended to introduce or cut off resistance coils, and may be used in practical work to regulate the operations of the steam engine driving the dynamo machines, or to regulate the number of such machines used for generating the current.

Mr. Haffey explained that the power for running the Sawyer dynamo machine furnishing the current was obtained from a bookbindery opposite the Institute, as the engine of the Institute could not be put in condition for the trial, but the latter could be used in making the proposed tests.

Prof. Houston having been called upon said that it was with some reluctance he arose to speak of electric lighting, inasmuch as he had a system of his own, in connection with Prof. Thomson. He had been asked, however, to describe the difference between voltaic arc lights and those produced by incandescence, and would do so.

In the voltaic arc lights there are two electrodes or pencils of carbon,

generally set one above the other, and when the current first passes they are in contact, but are withdrawn by an electro-magnet called into action by the current. The heat developed by the passage of the current from one electrode to the other, when they are separated, vaporizes the carbon and produces the phenomenon known as the voltaic arc. These lights are mainly used for large areas, and clockwork or electro-magnets are used to maintain the carbons at a fixed distance apart during their consumption.

In incandescent lamps there is no separation of the electrodes, but the current passes through some resisting material which is thus raised to a red or to a white heat by incandescence. In this lamp (the Sawyer) the current passes through a thin pencil of carbon, scarcely thicker than the lead in an ordinary pencil. There are a number of systems of incandescent lighting. The main difference between Edison's and Sawyer's lamps is that Mr. Edison uses a medium of very high resistance and puts it in a vacuum, while Mr. Sawyer uses a carbon of comparatively low resistance and puts it in an atmosphere of nitrogen. The Jablochkoff candle is made of two pencils of carbon set side by side and separated by a non-conducting material. In order to start the light a piece of conducting material is laid across between the two carbons. The current passes up one carbon, across the top and down the other carbon. The voltaic arc is soon formed at the top between the two insulated pencils of carbon. The positive electrode, from which the current passes, is consumed about twice as fast as the negative electrode, and with a direct current the candle would burn down more rapidly on one side than on the other. To avoid this the current is alternated so rapidly as not to affect the steadiness of the light, and each carbon being alternately the positive and the negative electrode the consumption is equally maintained.

Prof. Marks inquired whether anything had been determined as to the economy of the Sawyer electric light.

Mr. Tatham, the President, replied that nothing definite was known on the subject, and the cost was yet to be determined.

Mr. Nystrom inquired what was in the tube, and in answer to further inquiries Mr. Hatfield stated that the tubes were filled with nitrogen gas at atmospheric pressure.

Mr. Nystrom asked whether, when expanded by heat, the lamps did not break.

Mr. Sawyer said that no lamps had been broken by this or any

other cause, and that the lamps had been kept burning in cold weather in a house on Fifty-fourth street, New York.

Mr. Nystrom said that he could not see any material difference between this light and Mr. Edison's. One used a curved carbon, giving more surface for illumination, and the other a straight carbon.

Mr. Burk said that the essential difference between the Edison and Sawyer lights was that one used carbon under conditions in which it was supposed to be practically indestructible, while the other provided for slow combustion or destruction, with apparatus designed to feed the carbon as it was consumed. In order to have it thus fed it was necessary to use a straight pencil.

Mr. Nystrom made some inquiries as to the life of the carbon in the Sawyer lamp, saying that he had seen a piece of carbon half an inch long broken off in one of the lamps. As he spoke another piece was broken in the large lamp, but the lamp was immediately readjusted automatically.

Mr. Haffey said that the average consumption was not so great as might be supposed from these accidents; that the large lamps, by reason of imperfections in filling them with nitrogen, did not last as long as the small lamps, and that the connections for the large lamp were very imperfect. They were made, in fact, by an assistant holding together two wires, and the irregularity of the light in the larger lamp was due to the imperfect connection thus established.

Mr. Le Van inquired as to how many of the smaller lamps could be maintained per horse-power.

Mr. Sawyer said that the best result he had obtained was seventeen of the small lamps per three horse-power.

Mr. Le Van inquired whether this was indicated horse-power or ascertained by the brake, and when told that it was indicated, he remarked that this was not as satisfactory as the brake.

Prof. Houston said that he thought it was only fair to the systems of electric lighting now in use to add a few words as to their readiness to come before the public. The systems of voltaic arc and incandescent lighting are as old as 1840. The difficulty has been that of securing economy in the production of electricity. Until the invention of the Gramme machine electric lights were produced by batteries. With the discovery of the reaction principle of dynamo-electric machines electric lighting made a great advance. It will not be many years before electric lights take the place of gas. Arc lighting can

now save from fifty to sixty per cent. in the cost where a great deal of gas is used. There will no doubt be great improvements in the next ten years, but there are at present good systems ready for the market. The merit of the system exhibited to-night as an incandescent light is the arrangement in the lamp of a means of correcting itself if any accident should happen. You are not left in darkness if the carbon breaks, but the connection is at once restored. The speaker doubted whether any substance in any attainable vacuum, if raised to high incandescence, could remain unconsumed: he doubted also whether a piling up of the carbon could be prevented. A system which provided for consumption and breakage as does this of Mr. Sawyer's is better. But electric lights of all systems must be known by their fruits.

Mr. Briggs said that he had come to listen, but felt impelled to say something to the large audience which had unfortunately been deprived of a description from Mr. Sawyer. Within four or five years an enormous advance has been made in electric lighting. Step by step electricians have pursued the subject to overcome the disadvantages that have presented themselves, and many have been surmounted. Gas lighting, which was much simpler, required twenty years before it came into practical use. Now we are accustomed to its difficulties and have learned to submit to its evils. And so we will have to get used to this new system of lighting. The absolute amount of power required to produce an electric light is certainly much less than for gas. The thing to be accomplished is the economical division of the electric light. There are several forms of these lights, which Prof. Houston has described, but the voltaic arc lights are not suited to household illumination. These attempts to produce a light which shall overcome present difficulties are to be praised and encouraged, for out of them will come that success of the electric light to which we all look forward.

Mr. McKean having been called upon, said that nothing brought before the meeting seemed to him to have done justice to this light. He had seen the Edison light when it was a toy. It could be turned up and down like this. He had also seen the Brush and other voltaic arc lights, which give forth a great light, which cannot be turned up and down; but this to him had been a very interesting exhibition, because the light was entirely manageable. Here we have lights that will do for small or large rooms in a dwelling. One does not want a light in his chamber like the great voltaic arc lights shown in the

streets or at hotels, but we all want these manageable little lights that can be turned up or down at will. A very great step has been made in providing such a light for use in dwellings.

In answer to inquiries Mr. Haffey stated that one of the lamps had been in use in New York for two months, and that the life of the small lamps was reckoned at about three months or say 300 hours.

Mr. McKean inquired whether the cost of furnishing the light had been ascertained, when Mr. Haffey said that that question could not be answered, but he repeated his desire to have the Franklin Institute take the lamps and answer the question for him, after investigating the subject.

The discussion was closed by Dr. Norris, who stated that he had been informed that the Houston-Thomson lamp was entirely manageable and could be turned up or down at will.

HOT-PRESSED AND COLD-PUNCHED NUTS.

Amongst the most conspicuous and important of American trades is the manufacture of the various descriptions of heavy ironmongery, most of which is peculiarly American in character and application. Besides rails, spikes, wood screws, rivets, washers, etc., are large quantities of bolts and nuts of many different patterns, sorts and sizes, from the tiny ones used for the wagons, houses and furniture of the settler in the remote West, to the large and well-manufactured bolts and nuts employed for railway construction, for timber, bridge or viaduct building, or supplied to mechanical engineers to be finished by the aid of their tools, and ultimately to become component parts of engines or machinery. Where large quantities of bright finished bolts and nuts of the same form and size are in demand, they are frequently supplied completely finished to pattern to the mechanical engineer. The large demand for bolts and nuts and the prohibitory effects of the high rate of import duty have naturally led to a lively competition between manufacturers who seek to distance their rivals by reduction of price, by improved class of product, or by both. A noteworthy instance of this competition has engaged our attention through a trade pamphlet, printed some time ago by Messrs. McLaughlin Brothers, South Third Street, Philadelphia, and issued by Messrs. Hoopes & Townsend, of Buttonwood Street Works, Philadelphia; the

pamphlet itself deserves notice as an instance of the thoroughness and expenditure both of brain and money with which trade is pursued in America. It may be characterized as forming a treatise of sixty-eight pages, with numerous well executed engravings, upon the physical and mechanical properties of bolts and nuts formed by two distinct processes, and contains some points of scientific interest apart from its immediate trading objects. It appears that Mr. Sternbergh, of the Reading Bolt and Nut Works, Pa., is a large manufacturer of bolts and nuts, the latter being forged or hot pressed. Messrs. Hoopes & Townsend are manufacturers at Philadelphia of bolts and nuts, the latter being produced by what is suggested rather than affirmed to be new and peculiar machinery and methods for punching the previously formed nuts cold, that is, at the ordinary temperature of the atmosphere. Great advantages are claimed by the manufacturers as possessed by the nuts thus produced. At the Philadelphia Exhibition both these manufacturers were exhibitors, and some sparring took place arising from statements made in the newspapers as to the rival exhibits which eventuated in a challenge emanating from Mr. Sternbergh, and which was accepted by his rival. The conditions of the challenge competition will best be learned by quoting from Mr. Sternbergh's letter to Professor Thurston, Stevens Institute, Hoboken, N. J., under whose control the contest was ultimately conducted: "The question whether cold-punched or hot-punched nuts are the stronger is of no little interest, especially to the consumer, and one that cannot be determined by an *ex parte* test. I propose that you test the question scientifically and fairly as an expert, and publish the result for the benefit of the public; and, for the purpose, I would propose to roll a bar of iron, one or more sizes, and in the presence of yourself or representative, punch half a dozen or more nuts from each bar, with certain sizes of holes, after my manner of making hot-punched nuts. Then you take the remainder of the same bars down to Philadelphia, and let Hoopes & Townsend punch cold the same number of nuts from the same bars, with exactly the same diameter of holes in your presence, and deliver the nuts to you. Let them furnish their bars also, if they wish, to be punched in your presence by each of us. The nuts to be full thickness, equal to the diameter of their bolts, for say $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, or 1 inch rods, as you prefer. No part of either nuts to be cut away, except so much as may be necessary to make them of equal thickness, then tapped with the same tap, without reaming the hole of either

sort, then tested on steel bolts, turned exactly alike, and the breaking strain of the threads of each sort recorded. Both should be pulled in the direction in which they are punched, or both in the contrary direction, as you prefer, only both alike. Another test would be to have both sorts of nuts of the same diameter, thickness and size of hole, then force a round, conical mandril through them until they split open, keeping a record of the strain, and see which splits open first. Each establishment to be allowed to have a representative present during the fitting up of the nuts and the testing. Bolts made of good chrome steel, I think, would answer to strip the threads. Would you undertake the tests in the interests of the public?"

To this Professor Thurston replied that he should take great interest in the trials proposed, and would be ready to conduct them "in the interest of the public and of truth." The trials were accordingly proceeded with in accordance with the conditions, and in August, 1877, Professor Thurston forwarded an elaborate and exhaustive report of the results, which is given at length in the pamphlet before us. It is not necessary that we should go at any length into this report, some parts of which appear to us drawn out to an amount of minutiæ and prolixity scarcely warranted by the practical importance of the matters referred to. The more important results, however, are thus summarized by Professor Thurston:

"The results of the trial, taken as a whole, are conclusive in proving—First, that the cold-punched nuts possessed a much greater average strength, combined with greater rigidity and slightly greater uniformity than were exhibited by the hot-pressed nuts, and that the superiority was most strongly manifested in the trials by stripping stress. Secondly, that the cold-punched nuts exhibited a strength never attained by the hot-pressed nuts, but that such variations in the strength of both styles occurred as to have caused the hot-pressed nuts to equal and occasionally to excel in strength the weakest specimens of cold-punched nuts."

These experiments appear to have attracted the notice of Professor David Townsend, of the Franklin Institute, who in March, 1878, published a paper in the JOURNAL OF THE FRANKLIN INSTITUTE, under the title of "The Flow of Metals," which forms a valuable supplement in a scientific point of view to Professor Thurston's report. We shall refer to this report more at length; it is enough here to state that he has clearly elicited one or two points in relation to the punch-

ing of metals at ordinary temperatures which are new, or not previously clearly enunciated, and which are of much practical importance to boiler makers, iron bridge builders, and all concerned in the cold-punching of metallic plates. The facts given by Professor Townsend also give us the key or explanation of two of the main facts given but not explained by Professor Thurston, viz., that cold-punched nuts when tapped present a greater resistance than hot-pressed nuts to the stripping of the thread by tension of the bolt, and also a greater resistance to bursting by the forcible intrusion of a conical mandril. From the statements of these two documents, respectively, we may take the following as proved: That a well-made steel cylindrical punch can withstand being forced through a much greater thickness of malleable iron at atmospheric temperature than equals its own diameter, contrary to the long received but in every way erroneous empirical rule current among boiler makers and other workmen. Thus a punch of $\frac{7}{16}$ inch in diameter was forced through a rectangular block of iron of $1\frac{3}{8}$ inch thick. In piercing such a block the punch traverses about half the thickness of the block before any punching or core makes its appearance. Detrusion then commences and increases until the remainder of the core is forced out and the hole complete. The flat side of the block at which the punch enters becomes depressed, and the originally flat laminæ are bent down adjacent to the hole into curves, more or less conforming to the saucer-shaped depression given to the top surface and extending to a greater or less depth from the top into the block. From the fact that the punch penetrates to nearly one-half the entire depth before any burr is formed at the lower side, and from experiments made upon the relative specific gravities of the iron of the block, and that of the core forced out of it, it is concluded that during the earlier part of the penetration the metal displaced is forced to flow out laterally around the deeper part of the block, and that the remaining portion of compressed metal, or core, is not forced out until the circumferential resistance of the metal of the block or nut to further outflow equals or exceeds the resistance to shearing of the core from the metal around it. On these facts mainly, it is argued, depends the superior resistance of cold-punched nuts when tapped to "stripping" or "bursting." The bending down of the fibre of the iron all round the hole in the direction in which the punch is moved, so that the fibre, for a portion of the depth of the hole at least, is more or less perpendicular to the faces of the threads when it has been

tapped, is assumed to present a greater resistance to stripping than when the tap has acted upon the fibre arranged in flat laminæ or at right angles to the axis of the hole. Again, the outward flow of metal detruded from the upper portion of the hole into the metal of the block or nut produces increased resistance to bursting, on the same principle as the resistance to bursting in artillery is increased by construction in superimposed rings with initial tension, thus transferring in the case of the nut a part of the bursting strain acting upon the interior of the nut to the exterior portions of the same. In the new Austrian bronze field-artillery, designed by Colonel Uchatius, the initial strain of the outer layers of bronze upon the inner ones, to which the great resistance of these guns to bursting strain depends, is produced by means which almost exactly resemble in principle the results of cold-punching in these nuts. The practical advantages thus obtained are, we may admit, real, though their amount may not be great. The advantages assumed to be gained by the hooking down of the fibre of the nut, so as to approach perpendicularly to the resisting surface of the male screw, seem in no small degree fanciful. This bending, moreover, only applies to a fraction of the entire depth of the nut. The advantage obtained by the outward flow into the nut is probably more important, for no nut bursts, and no stripping of screw threads can take place, with a large amount of resolved strain produced radially by the sliding outwards of the threads of the nut by the pressure upon their inclined faces. The increment of strength, however, obtained by cold-punching from the above-mentioned physical causes, does not seem to be great, and by far the largest proportion of the superiority claimed for the cold-punched nuts seems to be due to the fact that the surface of the hole is perfectly clean and free from scale, while that of the hot-pressed nut is necessarily coated with more or less of hard scale, which may be as hard perhaps as naturally crystallized hematite. In the case of the hot made nut this is broken up by the forcible entrance of the tap, and forced more or less into the substance of the threads of the screw, dependent for their form on that of the tap itself, and upon the degree to which the latter cleanly cuts out the hollows between the threads, or merely moulds by pressure the metal of the nut to fill the spaces between them. But whether forced up or cleanly cut out, the threads of the cold-punched nut must be of solid iron and free from all adventitious mixture of scale, or "Hammerschlag," and in this consists what we deem to be the main advantage of a cold-

punched or drilled nut as compared with a hot-pressed one. A large portion of Professor Thurston's report is devoted to a needlessly prolix record of the experiments made to determine the relative cost of finishing, by machine tool work, the top and bottom faces and the sides of hexagonal nuts, made by both processes, the results being, as might have been anticipated, in favor of the cold-punched nuts. The tapping of any ordinarily proportioned nut constitutes a large proportion of the expenditure necessary for making it a bright finished one, perfect in all respects, and it is obvious that a nut, having a hole with clean cut metallic surface, will be tapped with less wear and tear of tools, perhaps even in less time, *i. e.*, admit of more rapid rotation of the tap, and ultimately will produce a better looking, more perfect and more resistant thread than will be produced from a scale-coated hot-pressed nut. But can these advantages be secured in no other way than by cold-punching, which, we apprehend, must be necessarily an expensive process, especially when deep nuts are manufactured—because the cold-punching process cannot be performed except at a very limited rate of speed? All that was meant by the old boiler makers' maxim that the thickness of the plate must not exceed the diameter of the punch, if more exactly expressed, was that with good steel and ordinary iron a punch, worked at the common speed of a punching press, will not stand long except under the boiler makers' condition. But it has long been well known that by forcing the punch much more slowly through the iron, perforations may be produced in plates greatly exceeding in thickness the diameter of the hole punched in them. The late Mr. Hick, of Bolton, showed many years ago that by slowly applied and continued pressure, holes to almost any depth or diameter might be produced, and, by means of the hydraulic press, he forced a disc of steel 6 inches or 8 inches in diameter through a piece of forged iron 2 inches or more in thickness.

Punching is but detrusion or changing the position of the particles of a solid, and time seems to be the only limit to the amount of this change of position producible by a given force. Even the most rigid and brittle bodies change their form without breach of continuity if sufficient time be given for the action of the detrusive force, as is evidenced by the distorted changes of form produced in strong univalve sea-shells, found embedded in laminated rock. It is somewhat remarkable that in neither of the documents to which we have referred do we find the slightest information as to the rate at which the perforation

of these cold-punched nuts is effected, and which, in the absence of any direct information, we are obliged to conclude to be slow. This, as in all other cases of manufacture, means that it is expensive, and may mean that the only real advantages of cold-punching are dearly purchased. Now, the most real of these advantages appears to be the freedom from scale of the hole in the punched nut, and unless the nut itself be punched out from a bar or plate of cold iron its surfaces cannot be free from scale. Now might not the advantage of freedom from scale be obtained much more cheaply than by the cold-punching process, and without any noteworthy deterioration of the resisting properties of the nut when finished? Might not the process of pickling applied to small castings be applied to hot-pressed nuts? We are inclined to think that little if any difference would be found between the cost of tapping and shaping or the perfection of thread attainable between the hot-pressed nut with the scale so removed and cold-pressed nuts. The process would be much more economical, but so simple an expedient would not afford a sufficiently distinctive standpoint upon which to claim superiority.

It is curious to remark that the challenger is not the victorious party in this competition, and considering the indirect or secondary motives which so frequently enter into these trade competitions, where all is ostensibly direct and fair, we are censorious enough to ask, was each party to this challenge so absolutely sure beforehand of winning as to risk the trial and the publication of its results, or was the whole thing but an elaborate puff got up in the best known style of scientific advertisement in which publicity is the main end in view on both sides? Where the average differences in resistance are within the comparatively narrow limits that these experiments indicate, it seems to us to approach special pleading to attach very great importance to the margin of superior resistance in the cold-punched nuts, especially in view of the admission that the abnormal result is occasionally found of a hot-pressed nut equaling or exceeding in resistance the less resistant of the cold-punched nuts. Now what prudent mechanician pushes to so fine a degree the dimensions of his bolts and nuts as to make it vitally important whether their passive strength falls short of or exceeds some assumed standard amount by 3 or 4 per cent.? Might not the advocate of the hot-pressed nut fairly argue that a very small addition to the dimensions of the bolt and nut made by his method will be sufficient to make it equal in all respects to the cold-punched

one; and how few must be the cases in which any practical objection can arise to such small necessary increase in scantling we surely need not urge!

We have for the sake of brevity abstained from reciting any of the numerical results obtained by Professor Thurston, given in his report and in the extensive tables attached to it. We have but scant information as to the hardness or softness, or tensile resistance of the irons respectively supplied by the two parties to the experiments, and here is a case in which variations in the physical properties of the iron employed would be certain greatly to vary the results obtained, as respects both hot and cold made nuts, more especially the latter. The iron of which the native gun barrels were made in India was often found so soft and ductile that a gun barrel could be cleanly severed through by a sword-cut, or even pared with a pen-knife; and we have irons of English make as hard and rigid as some of the varieties of steel. It is unnecessary that we should enlarge upon the differences that would result from experiments such as have been here adverted to, according as the iron employed neared one or other of the limits thus roughly indicated.—*Engineer.*

Combined Induction Machine.—The difficulty of exciting electricity in damp weather, or in rooms where many men are collected, has induced Robert Voss, of Berlin, to combine the Holtz and Topler machines. He retains the usual Holtz form. Instead of the four fixed half discs he uses one whole disc, which has about the same amount of paper covering as the Holtz. Upon this disc there are four tinfoil coverings, which are connected by couples with one another, and also with two brass pieces which are attached to the fixed disc. The pieces of brass upon the circumference of the disc serve as bearers for the gum stirrup in which the metallic brushes are fastened. The revolving disc has six tinfoil coverings, with an equal number of brass springs; the metal brushes press upon these springs. The double conductor of the machine has also two metal brushes rubbing upon the same springs. The free electricity of the air collects upon the tinfoil. In consequence of the turning of the rotating disc, and the contact of the metallic brushes with the brass springs, their electricity is increased and conducted to the paper covering of the fixed disc.—*Dingler's Journal.* C.

ELECTRICITY IN COLLIERIES.

The following letter from Mr. W. H. Preece, President of the Society of Telegraphic Engineers, has lately appeared in the London *Times:*

Several correspondents recently advocated in the *Times* the employment of electricity for illumination in collieries. One suggests that portable lamps made of a battery and a vacuum tube should be employed. Such lamps have been tried frequently, but they have failed from want of permanence in the current and of intensity in the light. I have seen excellent lamps of this form, notably one made by Breguet, of Paris; but they proved much too feeble in illuminating power in practice. Others propose the use of the electric light on the assumption that such a light is safe. It cannot be too strongly insisted that the absolute safety of the electric light is a popular delusion. In the first place, the arc itself is the greatest source of heat which science possesses, and, in the second place, the wires conveying the electric currents that produce the arc may themselves be conveying energy in a form as insecure as a train of gunpowder. The danger of the electric arc is supposed to be removed by its insertion *in vacuo* in hermetically sealed glass bulbs; but what if these bulbs be broken, and what about the difficulty in maintaining the vacuum?

Granting, however, that it be practicable to immure the light in a secure transparent vessel, what about the wires? The currents employed to generate the light are extremely powerful, in some cases many thousand times stronger than those employed to work telegraphs. Not long ago a poor musician in a theatre in Birmingham, and quite recently a Russian sailor on board the *Livadia,* were killed by incautiously seizing upon certain exposed parts of the conductors conveying these currents. The difficulty in maintaining currents in their proper path in telegraphy is very considerable. How much more difficult must it be to maintain those employed for electric lighting! Copper wires are carefully enclosed in india-rubber or gutta-percha coatings, but these insulating coatings are liable to injury; they are inflammable, and if a mere crack or pin-hole were to occur in such a coating, the currents would escape to earth, generating heat and producing fire. This view is not chimerical. Offices have been

set on fire even by the currents employed in telegraphy. I know of two such cases; one in New York, and the other in Boston. It is not at all unlikely that the recent fire at Manchester arose from such a cause. The liability to such accidents is evidently much greater with electric lighting, and it is only technical knowledge and professional skill which can render such currents innocuous even in well-constructed buildings. In mines, however, the difficulty is much greater. There the wires must necessarily be suspended in narrow, frequented galleries close to the damp earth, and be liable to incessant injury, and they could be rendered comparatively safe only by costly cabling. It would be impossible to guarantee absolute security. To light a colliery by electricity would therefore be both costly and dangerous. The popular delusion as to the safety of the electric light is probably due to its being so frequently spoken of as a cold light, the word "cold" being used in its figurative sense of *clueless*, the unscientific taking the word in its literal sense.

There is reason to believe that electricity plays another important part in colliery accidents. Some months ago there was a terrible disaster to the Risca colliery in South Wales; over 70 human beings were hurried into eternity. An inquiry was held into the cause of the disaster, and the conclusion arrived at was very unsatisfactory. A well-known telegraph engineer, Mr. Arthur Radcliffe, from evidence collected on the spot, arrived at the conclusion that the mine was discharged by a flash of lightning. He submitted his evidence to me, and I fully concurred with him. All the conditions of such a catastrophe were present. The flash of lightning was seen to strike the head-gear of the shaft immediately before the explosion. This machinery was connected with the bottom of the shaft by several continuous conducting masses. Iron rails, resting on poorly conducting matter, extended thence throughout the galleries. The gas was there, and it only wanted a break of continuity in the metallic masses conveying electricity, of which there were many, to produce sufficient heat to fire the charge. I have no doubt that lightning was the cause of the explosion. These facts were submitted to those who were concerned in the inquiry; but, probably, being incomprehensible to them, they were ridiculed and therefore ignored.

Hence I advocate the employment of well-constructed lightning conductors over the head-gear of shafts to keep electricity out of the

colliery and to insure safety, rather than the erection of conductors along its galleries to convey it in them for purposes of illumination and to court danger.

The following letter by Dr. Siemens is in reply to the above communication:

Mr. W. H. Preece, in addressing you under the title of "Electricity in Collieries," on the 28th of October, points out, very properly, I think, that the employment of the electric light would not be without danger in coal mines, because the electric arc and an accidental spark between conductors would be liable to fire a gaseous explosive compound. When examined before the Royal Commission on Accidents in Mines, I gave evidence to this effect, suggesting only an indirect application of the electric light, by which, if successful, the chances of accident would be minimized. I am not prepared, however to follow Mr. Preece in his assertion that the electric light generally and under ordinary circumstances is an illuminant dangerous to life and property; his statements in this respect have actually caused unnecessary alarm to those who have trusted electricity for the illumination of public buildings. Mr. Preece says that "if a mere crack or pin-hole were to occur in an insulating coating the currents would escape to earth, generating heat and producing fire," emphasizing this statement by asserting that it is not a chimerical one, but the result of practical information of his own. Now, the dynamo-electric current is powerful in the sense of doing a large amount of work, but its intensity is so moderate that it is only by rubbing the two unprotected conductors against one another that vivid sparks are produced. The interposition of a thin shaving of wood or other inflammable substance would in itself supply a sufficient insulating separator to prevent the spark, and I challenge Mr. Preece, notwithstanding his well-known skill as an experimenter, to the production of an igneous discharge through a mere pin-hole in the insulating covering of one or other of the conductors. In practically arranging electric lights for public buildings the insulated conductors are entirely separate, and the likelihood of danger to buildings is absolutely removed by the precautions taken. Mr. Preece's reference to the unfortunate musician and Russian sailor, who appear to have been struck dead by electric discharges while assisting to put up electric lights, is somewhat sensational. They must have been predisposed to succumb to an electric shock, and

must have grasped firmly the two unprotected leading wires with moist hands; for I and many other persons have frequently touched both poles of a powerful dynamo machine without feeling any the worse for it. At the same time there are dangers connected with the establishment of this, as of almost any apparatus or machinery, which do not in any way apply to the use, or, as upon courting danger Mr. Preece also charges the electric light with being cold in appearance, but in reality "the greatest source of heat which science possesses." Now, I quite agree with him in this latter proposition, and have, indeed, constructed an electric furnace for fusing highly refractory materials; but I wish to guard against the inference that because the electric arc is hot, electric light must necessarily heat rooms in which it is employed to anything like the same extent as gas or, indeed, any other illuminant. The following simple calculation, based upon actual experiment, will show what is the relative heating effect of the two sources of light within a room. To produce 1000-candle power by electricity requires a current of 34 Webers, which again represents 130 heat-units per minute. To produce the same amount of light by gas takes 200 Argand burners, consuming 16 cubic feet of 20-candle gas per minute, which consumption represents 15,000 heat-units. Some additional heat will be produced in the electric arc, however, by the combustion of the carbon electrodes, which consumption amounts to 6·3 grains of carbon per minute, and will produce in combustion 12·5 heat-units. The total amount of heat produced by the electric arc is, therefore, 130 + 12·5 = 142·5 units per minute, or rather less than 1 per cent. of the heat developed with the same amount of light by means of gas. Gas-lights produce, however, the further inconvenience of displacing the oxygen of the air by carbonic acid, and by a minor, but still very sensible amount sulphurous acid.

If this calculation militates against gas as an illuminating agent, it proves, on the other hand, its great value as a heating agent; and just now, when so much is said about the smoke nuisance, I may be allowed to add a few words on that subject. For upwards of 20 years I have been actively engaged upon the development of a system of working furnaces for the manufacture of iron, steel, glass, etc., by means of gas-fuel produced in a simple gas-generating apparatus. Some thousands of these gas-producers are in operation, and furnish daily proof that gas may be used with economical results; and the smoky factory chimney, where it still exists, proves simply a disregard

for the principles of economy. In the year 1853 I was anxious to take a further step in the same direction in proposing to supply towns with heating gas, and, having induced the Town Council of Birmingham to support my plans, measures were taken to obtain Parliamentary power to carry them into effect. It was intended to separate the two constituents of coal by a comparatively inexpensive method, supplying gas of low illuminating, but high heating power to consumers at a cheap rate, and reserving the coke for use in locomotive engines and stoves, for which purpose it is eminently better suited than raw fuel. Unfortunately, the bill was thrown out by a committee of the House of Lords in consequence of the opposition of the existing gas companies, and the proposal has remained in abeyance ever since. While it is admitted by many that gas fuel can be used advantageously for heating furnaces, there still exists great objection to its use upon the domestic hearth, which is one of the largest sources of consumption of raw coal, and certainly the cause of a great amount of smoke in our metropolis. The gas fireplace sometimes used does not meet with public favor, owing to its uncheerful appearance, great consumption of gas, and, most of all, from the smell which frequently results from its use. It is said to produce a "dry" heat—a term which to my mind conveys no definite meaning, seeing that the heat produced by an open fireplace is purely radiated heat, precluding the idea of moisture; but I have observed that in the usual gas grates, consisting of a number of gas jets spread over the grate, and covered in with pumice stone or asbestos, the heavy gases resulting from the combustion descend through the grate bars, and thus find their way into the apartment.

I have lately constructed in my own house gas grates that are certainly free from the defect just named, and which are at the same time economical and cheerful in their appearance. The arrangement consists in substituting for the fire grate below a solid plate, so as to exclude all communication with the atmosphere, except through the front bars.

A gas pipe perforated above with a certain number of small holes is connected to the ordinary gas service. The grate is filled with ordinary gas coke or anthracite, banked up well towards the back. In this way a cheerful fire can be kindled at any time by opening the gas tap and putting a lighted match to the grate. The gas flames, acting only in front of the grate, soon cause the surface of the coke to glow,

without depriving the beholder of the cheerful appearance of the flame. In the course of half an hour the surface of the heap of coke is fairly red hot, throwing out fully as much heat as an ordinary fire, while not a particle of flame or smoke reaches the chimney; the combustion of the gas prevents the rapid consumption of coke in front, and the absence of its consumption towards the back of the fire. When fairly ignited the gas may be almost turned off, because the coke, once well heated, continues to glow by slow combustion with the atmosphere. An ordinary grate may be converted into a coke gas grate as just described at a very trifling cost, and will be found convenient and inexpensive in its use even when using illuminating gas at 3s. 6d. per thousand cubic feet. Its economy will be materially increased by a sort of regenerative arrangement by which the heat gradually accumulating at the back of the fire is utilized to supply the gas flame with a current of hot air—an arrangement which it would take too much space to describe, but which I shall be happy to place at the disposal of the association recently formed with the laudable object of improving our winter atmosphere.

ADULTERATION OF WINES.

The French Government have just passed a most salutary measure, which will have for effect the diminution, if not the complete suppression, of the process known as *plâtrage*, now become an almost constant custom through most of the wine districts of France, and which, from having at first been performed on a very moderate scale, has lately enormously increased, till it has developed into a crying abuse. The *plâtrage* is carried on under the fermentation, and consists in merely sprinkling the grapes, as successive baskets of them are emptied into the fermentation vats, with plaster of Paris—calcium sulphate—(French *plâtre*), mineralogically known as gypsum, or selenite, in fine powder. Now the grape-juice contains several salts of potash, among which the most abundant are the tartrate and bitartrate, and these decompose when placed in contact with the calcium sulphate, forming calcium tartrate—an insoluble salt—and potassium sulphate.

In the case of potassium bitartrate, potassium bisulphate is formed. Now besides the salts of potash above named, the juice of the grape contains grape-sugar, a nitrogenous fermenting principle and an astrin-

gent principle—to which latter new red wines owe much of their harshness—and also a red coloring matter, with which the astringent principle is intimately associated. The fermentation splits up the grape-sugar, as it is well known, into carbonic acid, which escapes with effervescence, and alcohol, which remains dissolved. In pure undoctored wines, in proportion to the development of alcoholic strength, and as the wine by age tends to become more acid, potassium bitartrate separates as a crystalline precipitate, forming the chief constituent of the deposit in the casks known as *lees*, or, when it forms in bottled wines, as the *crust*.

Now the astringent principle which in the red grape is, as we have explained, intimately combined with the coloring matter, seems to be held more or less in solution by the tartrates, and as these subside with age the wine grows less harsh, losing at the same time much of its color, and is said to ripen or grow mellow. As the astringent principle, however, disappears, the wine, if it be one of the weaker French wines, tends to run to the acetous fermentation, and this is why we frequently find a wine become sour and unpalatable shortly after it has mellowed with age and arrived at its maximum of perfection. Many a bin of valuable claret or Burgundy has thus suddenly surprised and disappointed its possessor, changing in the short space of a few months from fine mellow wine to undrinkable vinegar.

Now, as stated above, calcium sulphate (*plâtre*) decomposes the potassium tartrates, and by withdrawing them and substituting the potassium sulphate, tends to prevent much of the coloring and astringent matter from passing into solution, so that this so-called *plâtrage* is nothing more than a means employed by the Bordelais and Burgundians for giving to their wines a fictitious effect of age, and they naturally defend a practice which enables them to bring their wines sooner into the market, economizing their outlay in casks, and diminishing the chances of loss entailed by keeping a large stock of wine on hand. Further, the process lends itself to fraud, permitting the wine merchants of Bordeaux and Burgundy to import the strong, harsh wines of the north of Spain and the southeast of France, which, when blended with the small, poorer wines of the hill districts of their own country, and then being *plâtrés* (that is, agitated with powdered calcium sulphate), become mild and palatable. Thousands of hogsheads of wines thus blended and doctored are annually sold, and too often at the high rates commanded by pure vintage wines. Under the

provisions of the new act no wine is allowed to be brought into commerce if it contains over two grammes of potassium sulphate per litre. Even this proportion is too large. *plâtrage* should be entirely prohibited; but when we consider that wines are now often sold with five or six grammes of this salt to the litre, it was time, indeed, that some measures should be taken. The merchants defend themselves on the basis of the practice being innocuous, and that while it promotes the keeping qualities of the wine, even four grammes of potassium sulphate could do no harm. It is the greatest possible mistake to fancy that *plâtrage* makes wine keep; for, on the contrary, it withdraws from it the astringent principle, a most potent means of its preservation. For a Bordeaux merchant to contend that forty grains of potassium sulphate to the pint of wine is not or cannot be unwholesome, is a thesis which may be agreeable to his pocket, but certainly ought to be discouraged, for, to say the least, it would surely be prejudicial to the stomachs of delicate or dyspeptic consumers. Not very many years since, a case occurred of actual death by poisoning from the administration of a comparatively small dose of potassium sulphate, and this salt is well known in medicine as a drastic and dangerous purgative. We should then be most sincerely grateful to the French Minister of Commerce for the prudent forethought with which he has protected the consumers of French wines from a practice which had grown into a crying abuse, and for giving us one more guarantee for the purity of these wines, justly ranked as the most esteemed that the world produces.—*Nature*.

SPIRAL POLARIZATION.

A beautiful illustration of the laws of polarization of light has lately been made by M. G. Govi. Let a parallel beam of light be passed through a polarizer, then through a thin slice of quartz cut perpendicularly to the optic axis, then through an analyzing Nicol prism. It is seen, as is well known, to be colored. This colored light when passed into a spectroscope gives a spectrum marked by one or more dark bands, corresponding to the particular rays whose relative retardations in passing through the crystal slice have produced interference. These bands are not always in one place; they are displaced right or left (according to whether the crystal is a right-handed or

a left-handed specimen) if either the analyzer or the polarizer be rotated. A slice of quartz about 4·3 millims. thick produces a single band. One of 8·6 millims. produces two bands at once in the visible spectrum, the number of bands being proportional to the thickness of the crystal.

Now suppose a mechanical contrivance by which both the analyzer and the spectrum can be rotated at the same velocity. A direct vision prism attached to the front of the Nicol prism realizes the optical portion of this combination. There will be seen on rotation a circular spectrum, having either red or violet at the centre and either violet or red at its outer circumference. Now since the dark band spoken of is displaced by a quantity proportional to the amount of rotation, interference will take place in this circular spectrum along points which form geometrically a spiral of Archimedes. The persistence of impressions on the retina will enable this dark spiral to be seen in its entirety, provided the rotation be sufficiently rapid. If a thicker piece of quartz be used, giving two, three or four dark bands, the rotation-spectrum will present a most beautiful appearance, being crossed by a two-branched, or three-branched, or four-branched spiral, the separate lines of which proceed from the centre to the circumference. The sense of these dark spirals will change with the sense of the impressed rotation. The effects, says *Nature*, are very striking.

Apparatus for Raising Water by Compressed Air.—Fr. Honigmann connects a series of casks, at various heights, so that the water is forced from cask 1 into cask 2. The expanding air drives the water from cask 2 into the higher cask 3, from cask 3 into cask 4, and so on until the elastic force of the air is entirely exhausted.—*Dingler's Journal.* C.

Flow of Compressed Air in Tubes.—M. E. Stockalper, the chief engineer at Goeschenen, has published the result of experiments made in the tunnel of St. Gothard upon the flow of compressed air in long metallic pipes, for the transmission of motive force. The special and very favorable conditions for performing the experiments, upon a scale which had been previously impossible, entitle his work to great consideration. His pipes were 5122 metres (3·17 miles) long and two decimetres (7·874 inches) diameter, and his results differ a little from those of previous observers.—*L'Echo Industr.* C.

French Lighthouses.—All the lighthouses on the French coast, except three which are provided with the electric light, have been lit since 1873 with lamps burning mineral oil. The luminous intensity of the apparatus has been greatly increased; and notwithstanding the increase a saving has been effected of more than 160,000 francs ($30,000) per annum, or more than 30 per cent of the cost of illumination with Colza oil. The use of the mineral oil has not caused a single accident in lighthouses, and after some trials it has also been brought into use for floating lights.—*L'Ingen. Civil.* C.

Nickel Plating by Boiling. Dr. R. Kayser prepares a bath of pure granulated tin, tartar and water, which he heats to the boiling point and adds a small quantity of pure red-hot nickel oxide. A portion of the nickel is soon dissolved, as is shown by the green color assumed by the liquid which stands upon the grains of tin. If articles of copper or brass are plunged into the bath they become covered, in a few minutes, with a white, beautiful, silvery metallic coating which consists almost entirely of pure nickel. If a little carbonate or nitrate of cobalt is added to the bath a bluish shade, either light or dark, may be given to the coating, which becomes very brilliant when it is properly polished with chalk or with dry sawdust.—*Mittheil. d. Bayr. Gewerb.* C.

Mineral Wool Packing.—In many cases steam pipes that were wrapped with mineral wool (slag wool) have become deeply rusted. It was at first suspected that the gypsum was the cause of the corrosion of the iron, but a careful analysis has shown that there were no sulphur salts, and it is now supposed that the rusting was due to the *hygroscopic* character of the wool. The following plan has been contrived for remedying the evil. Two-parted cast iron nuts are screwed upon the ends and in the middle of each tube, which serve as receptacles for wooden laths. The space between these and the tubes is packed tightly with the wool, about 5 centimetres (1.97 in.) thick, and the whole is wrapped at various places with iron wire, so that the envelope is bound fast to the tube. The laths are first soaked in tar, and the wrapping is also varnished with tar and then surrounded with a shell of sheet iron, which is also wound at different places with iron wire. The ends of the shell are placed in the nuts and these are also sealed with tar.—*Dingler's Journal.* C.

Gum Dynamite.—M. Leclaire found, in sinking a well through a bank of massive sandstone at Blanzy, that the charge of gum dynamite need be only two-thirds as great as the charge of ordinary dynamite. The first cost, 8.50 francs ($1.70); the second, 7 francs (1.40) per kilogramme (2 2 lbs.). The proportionate expense for equivalent effects is as 17 to 21.—*Mem. de la Soc. des Ing. Civ.* C.

The Diaphote.—Edison, Prof. Perosino at Mondovi, and Dr. H. E. Lichs, of Bethlehem, Pa., have all experimented upon the transmission by telegraphic wires of the forms and colors of objects in the same way as sounds are transmitted by the telephone. They hope to be able to contrive an apparatus by which two persons who are separated by an ocean will be able to see and hear each other.—*Les Mondes.* C.

Statue of Father Secchi.—The Roman municipality has erected a statue to Father Secchi, of heroic size, on the beautiful promenade of the Pincio. The expression of the great astronomer has been copied with wonderful fidelity. His animated eye is fixed upon the Observatory. He wears the Jesuit dress, with an eye-glass attached to a little cord suspended from his neck. His mantle, falling in numerous graceful and natural folds, hangs from the right shoulder.—*Sem. Relig. d'Autun.* C.

Sidewalk Astronomers in Paris.—At a late banquet to the scientific press Camille Flammarion read a letter of thanks, which had been addressed to him by the street exhibitors of telescopes, in which they stated that the number of their patrons had more than doubled since the publication of his *Popular Astronomy.* Some of the instruments upon the Place de la Concorde would not be unworthy of a place in an observatory.—*Les Mondes.* C.

Influence of Colors upon Animal Development.—C. Yungby, experimenting upon marine animals, has confirmed the results of his fresh water experiments. Eggs of *Loligo vulgaris, Sepia officinalis, Rana esculenta, Salmo trutta* and *Cymnea stagnalis* were developed most rapidly by violet and blue lights, while they were retarded by red and green. Scarcely any difference was observable between the yellow and white lights. Unlike his previous experiments, the development, although retarded, was nevertheless accomplished in red and green vessels.—*Comptes Rendus.* C.

Sun Spots in 1879.—Wolf has compared the solar observations at Zurich, Palermo, Rome, Moncalieri, Athens, Madrid, Leipzig, Peckelöh and Washington, obtaining for the epoch of minimum 1878·9. The variations in magnetic declination at Milan, Vienna, Prague, Munich and Christiania indicate the minimum epoch 1878·5. Both results agree in pointing to an epoch of 11·7 years.—*Compt. Rend.* C.

New Method of Road Building.—Oppermann proposes to build highways in two layers: 1, a bed of 15 to 20 centimetres (5·9 to 7·87 inches) of coarse beton with hydraulic mortar; 2, a bed of smaller beton, cemented with a mixture of lime and one-half part of Portland or Boulogne cement and one-half part of slag. The stones in this second bed should be chosen exclusively from the hardest and most flinty varieties.—*Chron. Industr.* C.

New Experiment upon Spectral Rays.—L. Thollon has erected an apparatus for spectroscopic observations upon the hill of the Nice Observatory. He has especially studied a group of four rays situated in the orange, two of which belong to iron and two are telluric. When the rays are received from the centre of the disc the telluric rays are nearly equi-distant from the iron rays; but if the rays are taken from the eastern or western side of the disc the iron rays are displaced while the telluric rays remain invariable. It is thus possible to demonstrate Fresnel's formula for light, as well as for sound, and daily to submit one of the most important laws of physical astronomy to careful verification.—*Comptes Rendus.* C.

Book Notices.

POTABLE WATER.—How to form a Judgment on the Suitableness of Water for Drinking Purposes. By Charles Ekin, F. C. S. 12mo. J. & A. Churchill. London. 1880.

This little book is addressed to those who practise sanitary water analysis in the hope of doing something toward extricating this important subject out of the unfortunate entanglements in which it has of late years become involved. When chemists of the highest reputation mutually denounce each other's methods of analysis, and each regards the one he himself has invented as "the only trustworthy process in existence;" and when chemists of these several disputes differ so widely in their certified opinions, that samples of the very same

water collected at the same time are considered by one chemist as perfectly wholesome and by another as positively dangerous for drinking, it is not strange that the public are scandalized and declare water analysis an absurdity. This lamentable result has been brought about, to a great extent, we are sorry to say, by a selfish intolerance manifested by both Dr. Edward Frankland and Mr. J. Alfred Wanklyn and their respective partisans. Such opposing factions, for such they really are, unfortunately are by no means unknown in other branches of science, and are to be found in this country as well as in England.

It is sufficient, however, to say here that the effect of such a state of things, probably more than anything else, is to retard the discovery of truth and seriously to check the very desirable popularization of true science.

It is the purpose of Mr. Ekin to endeavor to clear up the atmosphere and to bring into view some of the most important facts to be noted in forming a judgment of a water. For this he appears to be well fitted by a practical experience in the analysis of nearly 2000 samples of water, many of which were well waters, unquestionably intimately connected with typhoid fever and other serious diseases. In a large number of cases he was able to make a personal examination of the premises and he practised chiefly in a district which included within thirty miles radius every geological formation from the chalk down to the silurian. It can scarcely be denied that the latter circumstance is of nearly as much importance as the preceding for the purpose of arriving at general conclusions.

After giving a very brief review of the ordinary sources of supply, and the character of water from each, he proceeds to criticise the merits of the several processes used at the present time to determine the amount of organic impurity. In the course of his remarks he says, "The custom of laying the chief stress on the amount of organic matter, irrespective of its origin, is misleading and fallacious." On another page he states, after speaking of the non-injurious character of even considerable amounts of peat in solution, "On the other hand, it is quite a common thing to find shallow-well waters containing large amounts of nitrates, exceptionally free from organic matter. Waters which have undoubtedly given rise to typhoid fever have been found by the writer over and over again not to contain more than 0·05 parts of albuminoid ammonia per million" (which represents the amount of organic impurity ruled by chemists as perfectly allowable in drinking

water) "and which, notwithstanding their containing a large excess of nitrates, have been passed by analysts of undoubted ability as being fit for drinking purposes." He gives as an instance of this a village situated on the porous Oolite rock, which also strikingly shows how a disagreement of judgment between chemists of high reputation may effectually put a stop to all attempts at sanitary reform in cases greatly in need of it. In this instance, the numerical results of the analyses were identically the same, but the respective opinions founded on the analyses were directly contrary one to the other.

Mr. Ekin records his conclusions in the following terms:

"A fair trial of the different processes leads to the conclusion that all are absolutely worthless so far as distinguishing between organic matter that is dangerous and organic matter that is innocuous is concerned, but that probably all may be relied upon as giving a rough approximation as to whether organic matter is in excess or not. * * * As giving any indication, however, of the wholesomeness of a water they are useless, because both vegetable and animal organic matter (the latter only being dangerous) yield organic carbon and nitrogen and albuminoid ammonia, and in proportions so nearly alike as to be practically undistinguishable."

This statement should be understood to refer to the direct estimation of the organic matter only, without any auxiliary tests. It has been stated by some, but denied by other chemists, that the presence of peat may be detected by the manner in which the albuminoid ammonia distils over. "An excess of organic matter," Mr. Ekin further says, "is not necessarily an objectionable feature in a drinking water, for many of what are confessedly our best and purest supplies contain an excess of organic matter; but neither, on the other hand, is a minimum of organic matter necessarily a satisfactory feature; for water from wells, especially from shallow wells, and which has undeniably given rise to typhoid fever, will frequently be found to contain only a minimum quantity."

"Therefore, the quantity of organic matter a water contains affords no guide" [considered exclusively by itself, our author should have added] "to its wholesomeness and to lay the chief stress on this ingredient, irrespective of other considerations, is as unscientific as it is eminently misleading."

One of the chief points of dispute has been the value of the determination of nitrates, Wanklyn rejecting it as of no value whatever and

Frankland considering it of prime importance, but making use of the results in a way that is very objectionable to represent a part of what he styles "previous sewage contamination." Now nitrates, when in excess of that derived from the natural soil and rain water, generally result from the oxidation of extraneous organic matter, which oxidation is aided by percolation through soil. But although the deeper the well the more thorough the filtration, Mr. Ekin is manifestly right in saying that the danger is only lessened, not removed, and that "experience shows that so far as infected water is concerned no amount of possible percolation will remove the poison."

The objection often heard, that nitrates and nitrites are not of themselves unwholesome is granted as perfectly true, but is nevertheless entirely irrelevant, and shows a complete misapprehension of the main point at issue. Mr. Ekin further states that nitrates in amounts of 0·3 to 0·4 parts per 100,000 are allowable as equivalent to that found under healthy and natural conditions. "When the amount exceeds 0·5 or 0·6 parts it points significantly to dangerous pollution, and examination of the ground almost invariably shows either that the ground has been heavily manured, as in garden ground, or that there is some actual infiltration of sewage."

Our author has stated his case in all probabili ty much too strongly As waters yield an excess of nitrates above the limit named they become *increasingly suspicious*, would have been a much more philosophical statement.

Owing to the possible occurrence naturally in the soil of larger quantities of nitrates than usual, the limit for condemnation should probably be somewhat higher, say from 1·0 to 1·5 parts per 100,000. But in reality *no one figure can be fixed* as a standard for all conditions of soil, etc., but each particular district must be judged on its own merits.

Understanding Mr. Ekin to signify that the determination of organic matter by the Wanklyn or the Frankland process is not wholly without value when taken in connection with the nitrates and nitrites, but may be in very many cases entirely valueless without them, the writer of this critique earnestly recommends this little book to the careful attention of chemists and sanitarians. His own experience in water analysis leads him to coincide very much with the views expressed by Mr. Ekin; at the same time, he wishes that some of his statements had been made in somewhat more guarded language. R. H.

Sewers and Drains for Populous Districts. By Julius W. Adams, Chief Engineer of the Board of City Works, etc., Brooklyn. 8vo. New York: D. Van Nostrand. 1880.

In the copy of the work before us the publisher could not have incurred censure if the subject matter had been a memoir or poem, so tasteful is the binding, paper and printing, and this would seem to indicate that the intelligence of the reading public no longer consigns such works to an obscure shelf.

The author states in his preface that in 1857 he prepared the plans for the sewering of the city of Brooklyn, covering an area of twenty square miles. It therefore has the advantage of being the production of a practical man of over twenty years' experience, as the title-page states that he is still connected with the City Works and Board of Health of that city. We quote the following paragraph, believing it to be in accord with the views of all who have given the subject any attention:

"The results of all inquiries abundantly demonstrate that drainage and sewerage are essential elements of health in populous districts. Independently of actual loss of life, which so frequently attends their neglect, impaired mental or bodily vigor, arising from the influence of defective drainage and sewage, reduces daily in thousands of cases the capabilities of individuals to such an extent that it may be considered equivalent to a loss of income by the deterioration or diminution it induces in the effective services which each can give to his occupation. Calculated as a matter of profit and loss, everything indicates that the expense required in establishing proper measures to avoid these evils would be far below the loss consequent upon the inefficient arrangement too frequently witnessed at present."

In view of the fact that thus thousands of persons in a large city may, through ignorance or carelessness, have the tone of their health depressed by disregarding the presence of foul air in their houses, and thus form a fertile soil for the germination and propagation of disease by a continuous subjection of their systems to an insidious poison, is it not a serious question whether it is not a subject eminently within the province of legislative action and governmental control, associated as it is, so vitally with the interests of each individual of the community, both as regards contagion and pecuniary loss? for it is not to be forgotten that epidemics are expensive visitations; the question presents itself in this practical form. Were this doctrine enforced, it would doubtless be resisted as an invasion of private rights, and it would be

claimed that unless one directly injured his neighbor he was entitled to maintain any condition of air he saw fit within his own house, and that even the probability of consequences indirectly involving his neighbors would not justify interference. As there is, however, strong cumulative evidence connecting cause and effect, the question resolves itself into one of degree, in fact, whether it could not be pronounced a nuisance, and suppressed under the statutes authorizing the authorities to abate public nuisances.

We regard Mr. Adams' work as a valuable contribution to the literature upon this subject, and we would particularly recommend it for the attractive manner in which the valuable information it contains is conveyed to the reader. We think, however, that upon the important question of a double system of conduits, one being for house sewage and the other for rainfall, our author is mistaken in assuming the strongest reasons in its favor to be the preservation of the rainfall uncontaminated for domestic purposes, and the undiluted house sewage for commercial use; he overlooks what seems to us a far more important reason, and one which he has touched upon incidentally in another part of the work, viz., the self-cleansing feature which would be thus introduced into that portion of the system allotted to house sewage, instead of having a varying water-line in a large sewer, depositing greasy collections at various levels, and leaving them for days to putrefy. By this method they would receive a daily scouring, if properly constructed; thus these immense manufactories of sewer gas which we maintain under our cities would, for several reasons, be rendered much more scientific in their arrangement.

We are strongly inclined to the belief that if the separation were complete, the washings from the street, contaminated only by the manure of animals, etc., for the most part pulverized and acted upon by the sun and air, would not produce sewer gas, even though the streets were neglected, as they so often are; for, from our point of view, the greasy kitchen refuse plays a large part in the contamination of sewers.

We would, in closing, congratulate Mr. Adams upon having produced such an admirable handbook upon a subject the importance of which is appreciated by all classes, and presenting problems which it is of growing importance should be solved. There is also added to the work, as an appendix, a paper upon the main drainage of London, with map, by the Constructing Engineer, Sir Joseph Bazelgette. We

would also direct attention to the fact that the work is embellished by appropriate cuts wherever the subject requires them. W. B. C.

Catalogue of Books and Papers relating to Electricity, Magnetism, the Electric Telegraph, etc., including the Ronalds Library. 8vo. London: E. & F. N. Spon. 1880.

We learn from the preface of this remarkable book that its compilation was commenced many years ago by Sir Francis Ronalds, and was continued up to his death in 1873. The titles of over 13,000 entries are arranged under the authors' names, anonymous books, with some attempt at classification, filling 14 pages alone, and being under a separate heading at an appropriate place in the volume.

An ardent lover of books, and at the same time a great reader of them, the principal occupation of Sir Francis Ronalds, during his residence of many years on the continent, was in the formation of this library and the compilation of the catalogue. Many works belonging to Volta, Arago, Faraday and other distinguished men, are among its treasures. As the date and place of birth and, where possible, of the death of each author have been added, the usefulness of the catalogue has been greatly increased. Papers contributed to transactions and proceedings of learned bodies, scientific periodicals, etc., have also not been forgotten, and the work is a perfect treasure of information to the ambitious student desirous of learning what has been done before him, and a key to unlock a great storehouse of knowledge. We cannot help but congratulate the Society of Telegraphic Engineers, of England, upon having secured this very valuable library, which has taken a lifetime to form, upon the simple conditions of binding the books and printing the catalogue. Originally intended, it is supposed, for the Royal Society, it was represented to its owner that many of the books would be simply duplicates in its already large collection, and when it was bequeathed to his brother-in-law, the latter thought he was best carrying out the views of Sir Francis in giving it to the Society of Telegrapic Engineers upon the above conditions. As the library will be open to the public the wisdom of the choice is apparent, for the best possible use of books is in their diligent study and the application of the lessons of wisdom they teach.

A biographical memoir, giving the leading particulars in the life of this earnest student of science and pioneer in the invention of the electric telegraph, is not the least interesting part of the volume. N.

Franklin Institute.

HALL OF THE INSTITUTE, November 17th, 1880.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

There were present 134 members and 13 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that 19 persons were elected members of the Institute at their last meeting. Also, that he was directed to advertise in the Journal of the Institute the proposed award of the Elliot Cresson gold medal to Mr. Louis S. Spellier for his invention of the Electric Time Telegraph.

The Secretary reported the following donations to the Library:

Specifications and Drawings of Patents, for February, 1880.
From the Commissioner of Patents, Washington.

Bulletin of the Philosophical Society of Washington. Vols. 1 to 3.
From the Society.

Report on the Culture of Sumac in Sicily.
From the Commissioner of Agriculture, Washington.

Proceedings of the Special Meeting of the Board of Supervising Inspectors of Steam Vessels held at Washington. 1880.
From the Board.

Report of the Department of Public Works of the City of New York. From the Department.

Memoir of Joseph Henry. By W. B. Taylor. Washington, 1880.
From the Author.

Summary of Researches in Sound: conducted in the Service of the Lighthouse Board. By Joseph Henry. Washington, 1879.
From the Lighthouse Board.

Philadelphia Water Supply. Report of the Commission of 1878. By Jas. Haworth. From the Author.

Contagious Diseases of Domesticated Animals. Washington, 1880.
From the Commissioner of Agriculture.

Erster Jahresbericht des Vereins für Erdkunde zu Metz, pro 1878.
From the Society.

Burley's United States Centennial Gazetteer and Guide. 1876.
From W. C. Desmond, Philadelphia.

The Millers' Journal and Flour and Grain Reporter. A weekly publication by Howard Lockwood. From Mr. Lockwood.

The American Miller. A monthly journal devoted to the Art and Science of Milling.
From the American Miller Publishing Co., Chicago.

The Daily Miller and Millwright.
From the Miller and Millwright Publishing Co., Cincinnati.

Report of Proceedings of Thirteenth Annual Convention of the American Railway Master Mechanic's Association, May, 1880.
From the Association.

Lecture on the Improvement of the Danube at Vienna. By Sir G. v. Wex. Translated by Geo. Weitzel. From the Translator.

Biographical Sketch of James Aitken Meigs, M.D. By George Hamilton, M.D. From the Author.

Mr. William Woodnutt Griscom, of this city, presented a paper on electric motors (published in another part of the JOURNAL), which was read by the Secretary, and illustrated by the use made of a small motor invented by Mr. Griscom. In this beautiful machine the current is converted into mechanical force by means of an electro-magnet, which, through the action of the commutator, alternately attracts and ceases to attract an armature. Credit was given to Professor Henry for having first used electro-magnetic force as a motive power, and some of the earlier motors of this kind were described. Mention was also made of the fact that Mr. Joule had demonstrated that the force yielded by the consumption of zinc in a battery is nine times as costly as the force yielded by coal used to convert water into steam. It has been concluded from this that electricity from a battery can never compete with steam, but this the paper declared to be an erroneous conclusion, since man power is still more costly, and yet for certain kinds of work and under certain conditions it is employed. The electric motor is particularly designed for household use in driving sewing machines, etc., the advantages claimed for it being readiness at all times to do the work, cleanliness, freedom from danger or disagreeable smells. This motor utilizes the attraction and repulsion of electro-magnets, converting magnetic resistance to motion into a counter-

electro-motive force, thus retarding the consumption of zinc in the battery. A sulpho-chromic battery, enclosed in a water-proof box is used, and, it is said, only requires renewal once in several months, or a year, in proportion to the amount of work done by it. The motor can give any desired speed to a sewing machine, from twenty to two thousand stitches per minute, depending upon the battery power, and this is very simply regulated by the operator pressing upon the treadle of the machine, and so raising or lowering the zinc plates in the battery. The power is sufficient to sew leather, or as much tightly woven linen as can be put under the presser. The motor is very small, not more than four inches long and two or three inches in diameter. It weighs less than three pounds, and is carried on an iron fork on the back of the table of the machine, so that the tension of the belt can be easily regulated. With the battery power used on Wednesday evening, the sewing machine was run at a speed of 800 stitches per minute, which was readily controllable down to 20 stitches per minute.

Mr. Griscom, in answer to queries, stated that each cell of the battery held about a gallon of the solution, that there were six cells with zinc plates, four by two inches, which only required to be amalgamated once. There were two carbon plates to each zinc plate, one on either side. The price of the motor had not yet been fixed, as it has not been put upon the market. As the plates are very small in proportion to the depth of the cells, the battery does not run down soon. Mr. Griscom had had one battery in constant use for ten weeks without changing the solution or renewing the zinc.

Mr. Bullock said that the difficulty about this form of battery had been overcome, as he understood it, by increasing the depth of the cells, the deposit of salts in these deep cells setting up currents which constantly brought fresh liquor to the plates.

Mr. Griscom said that was the true explanation of the maintenance of the battery.

Dr. Norris said that he remembered some experiments he had tried at the Central High School a number of years ago, where the carbon and the zinc were placed in a beaker glass and the bichromate solution then added, the heat from a spirit lamp being used to keep up the circulation of the fluid with the same object as Mr. Bullock had mentioned. He added that there was no objection to the use of a battery for furnishing the current to a domestic motor, as men could be employed to visit houses and attend to the batteries with no more trouble

to the householder than the gas inspector who comes to examine the meter, provided only they were generally used.

The Secretary's report of new inventions included the following: Spellier's Pendelum Suspension applied to small clocks. The object of this compensation is to keep the centre of gravity, regardless of change of temperature, at an equal distance from its centre of oscillation, so its suspension should allow only its recurring oscillation to follow the track of a straight line and to move in one plane only. To give this result it is necessary that the suspending spring should have an even tension. In Spellier's invention you have a contrivance which will automatically adjust the tension of the suspending spring and thus avoid all wobbling motion. As the weight bears equally on either side of the spring, by means of the pulley motion, the tension is adjusted automatically.

A stem-winding clock, imported by the Messrs. Bailey of this city, was also shown. No openings are required upon the dial of the clock which is wound by the keys that can be pushed in and out, and are concealed by the metal frame holding the glass over the face, thus adding much to the beauty of the clock.

An improved folding bed was exhibited by Shupe and Noble. When closed it presented the appearance of a secretary, but was readily opened and changed into a strong bedstead furnished with springs and with room enough inside for a mattrass, bed clothes, etc. These folding bedsteads are made to represent almost any desired piece of furniture, such as a bureau, secretary, sideboard or dresser. The one exhibited was mounted on Martin's patent castors, which were separately shown. These castors have two wheels with a friction wheel directly above the centre of the axis, so that the pressure of the piece of furniture mounted on them is direct. It is claimed that they will sustain great weights and yet move easily.

Attention was called to Professor John M. Child's modification of Galileo's experiment to determine the velocity of a falling body. This apparatus consists of two parallel bars mounted upon a frame so that they may be inclined to the horizon at any angle desired. Two wooden cylinders of the same size, and rigidly fastened to the same axis, roll down the bars. On the axis between the two cylinders is fastened a metal collar which turns freely and which has two arms extending outward. At the ends of the arms are fastened two cords which support the bob of a sand pendulum made of a length to vibrate in

one second. This pendulum swings at right angles to the direction of the motion of the cylinders, and when the cylinders are at rest marks by its sand trace a straight line, an axis of ordinates. On allowing the cylinders to roll down the incline while the pendulum swings, we form a curve which crosses the axis of abscissas at intervals of half a second. The portions of the axis of abscissas contained between these two intersections are found to be proportional to the numbers 1, 3, 5, 7, 9, etc. From the measurements of the curve so formed all the simpler laws of falling bodies may be deduced.

The special merit which the inventor claims for this instrument is that the trace left may be examined at leisure, and thus time is afforded for the mind of the student to grasp the truth elucidated, while the illustration remains before his eyes.

The curve formed by this instrument differs from the simple sinusoid that is formed by the trace of a pendulum moving with uniform motion, in the fact that the abscissas described in the times 1, 2, 3, 4, etc., instead of being proportional to the times, are proportional to their squares, 1, 4, 9, 16, etc. The equation of the curve is, therefore, $y^2 = \sin x$.

This apparatus also affords us a means of computing the distance that a body falls freely by measuring the distance the cylinder rolls in a second, and the angle of elevation of the inclined surface. To attain this result satisfactorily the inclination should be made at least as great as 15° or 20° in order to diminish the retarding effect of rolling friction.

The Secretary presented specimens of graphite, lead pencils, axle grease, etc., from the Dixon Graphite Company of Jersey City.

Mr. Orr inquired where the mineral came from, and Dr. Norris replied that this was the home article, but he believed supplies were also received from Siberia.

Professor Frazer said that some graphite came from the Champlain district of New York, but that some of the finest specimens he had ever seen came from Chester County. Mines near Phœnixville, only a few miles from Philadelphia, furnish much of the best graphite now used.

Mr. Burk exhibited two Jablochkoff candles and described them. He said that they had recently been introduced in this country, and that they were now employed in lighting the store of a silversmith on Chestnut street. Four massive lamps of an ornamental pattern are

used in the store, replacing 120 gas burners. They are said to yield 550 candle power each, and light the store more efficiently than it could be lighted with gas, and without any flare or flickering of the light. The current is furnished by a Siemen's dynamo-electric machine driven by a steam engine of ten-horse power, though it is said only five-horse power is required or used. Each lamp contains six candles, and each candle lasts about an hour and a-half. An automatic arrangement, which may also be operated by hand, switches the current from one candle to another as the one is consumed, so that the light in one lamp can be maintained continously for nine hours. The burned candles are replaced by others at a cost of five cents each. The light given forth through porcelain shades is very soft and agreeable and remarkably steady, notwithstanding the fact that an alternating current is employed, whereby each of the two carbons composing a candle is alternately positive and negative. It is said that there are over two thousand of these lamps in actual use in Europe, but they have only recently been introduced in this country.

Under the head of deferred business, the Secretary read the report of the Committee on Meetings, adverse to the resolution offered by Mr. Eldridge for the printing of reports of papers read at meetings of the Institute.

Professor Frazer's resolution, offered in April last, providing for the appointment of a committee to examine and report upon the methods of testing inks for iron, employed by chemists who testified in the Whittaker will case, was called up. Professor Frazer said that he would have asked for its consideration before, but for the fact that he could not attend at previous meetings. The resolution, he said, was worded rather clumsily and not as he would word it to-day, now that the trial is ended. The object is to ascertain in an authoritative manner the best tests for ink. He had discussed the idea of having a committee of the Institute pass upon the methods of experts before the Whittaker will trial, in the belief that scientists, freed from the restraints put upon them in a court of law, could get rid of a great deal of verbiage on the subject and develop the best methods of analysis. Only a day or two ago he had received a letter inquiring whether certain tests for iron had been disputed by expert chemists. He said that the old objection to the proposed inquiry had passed away, since the law suit had been decided, and he thought the resolution providing for the appointment of a committee ought to be adopted. The reso-

lution for the appointment of the committee was agreed to without dissent.

Notices having been given by Mr. Cooper and Mr. Eldridge of two amendments to the by-laws, one of which prohibited proxies at elections, and the other provided for them, Mr. Cooper explained that at the last election three proxies had been presented, and there being no law on the subject the tellers did not know what to do with them.

Mr. Eldridge said that he had presented his proposed amendments so as to bring both sides of the question before the members. They could adopt one or the other, but in either case they would get a law on the subject.

On motion, it was resolved to publish both notices, so that both amendments would come up at the next meeting to be acted on.

A paper signed by Wm. B. Cooper and Lewis S. Ware was read by the Secretary, advocating the removal of the Institute from its present to more commodious quarters, and the holding of an exhibition next year, from which to raise funds to carry out this purpose.

Mr. Cooper offered a resolution adopting the paper presented by himself and Mr. Ware, and referring the subject matter thereof to a committee of five to be appointed by the President.

Mr. Ware seconded the motion in a speech, showing the danger from fire which the library of the Institute is exposed in its present building.

Prof. Frazer said that it seemed premature at this time to ask the meeting to adopt anything. He could see no objection to the appointment of a committee to consider the subject, but thought that no definite action ought to be taken without such consideration.

Mr. Cooper withdrew that portion of his resolution providing for the adoption by the meeting of the paper presented, and upon motion, it was resolved, that the Chair be authorized to appoint a committee of five members to consider and report at the next meeting upon the communication read.

Mr. Eldridge moved that the subject of the discussion of papers being made the order for the next meeting following the reading, embodied in a resolution previously presented by him, be referred back to the Committee on Meetings, with instructions to consider the advisability of having this made an order of business independent of the question of printing the papers, but it was not agreed to.

On motion the Institute then adjourned.

ISAAC NORRIS, M. D., *Secretary.*

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